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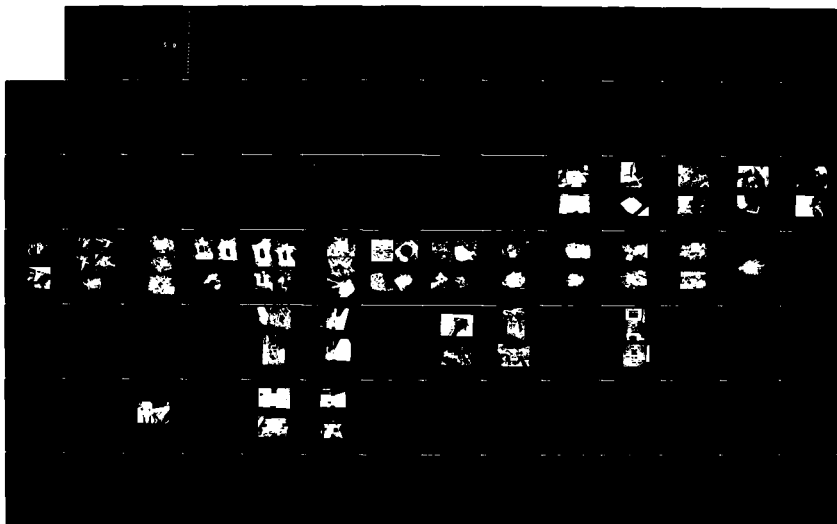
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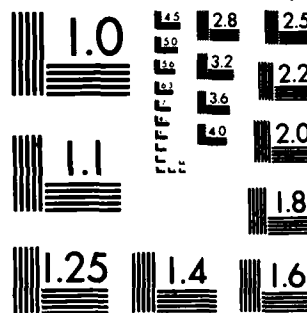
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Report No. AMXTH-TE-CR-86091

Installation Restoration General Environmental Technology Development.

Contract DAAK 11-82-C-0017 (Task Order 9)

Field Demonstration of Incinerator Feed System For Explosives-Contaminated Soils.

Volume 2.- Appendices.

January 1987

Distribution Unlimited; Approved for Public Release

Prepared for:
U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
Aberdeen Proving Ground (Edgewood Area), Maryland 21010

Roy F. Weston, Inc.
West Chester
Pennsylvania 19380

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the results of field demonstration project to evaluate the suitability of an incinerator feed system for conveying explosives-contaminated soils. The project was conducted at the Louisiana Army Ammunition Plant from 30 June to 10 July 1986. This report presents the test variables, schedule of tests and runs, data analysis, and conclusions and recommendations for future field implementation.		

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APPENDIX A
SUMMARY OF INCINERATOR FEED SYSTEM DEVELOPMENT

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WESTON WAY
WEST CHESTER, PA. 19380
PHONE: (215) 692-3030
TELEX: 83-5348

20 February 1985

Mr. Wayne E. Sisk
COR
USATHAMA
ATTN: DRXT11-TE-D
Aberdeen Proving Ground
Edgewood Area, MD 21010

REFERENCE: Contract DAAK 11-82-C-0017
Task Order No. 9
Summary of Incinerator Feed
System Development

Dear Wayne:

In accordance with your request, please find attached a brief report summarizing the background, current status, and planned activities regarding the incinerator feed system development. In summary, WESTON is confident that a screw conveyor feed system represents the most advantageous alternative for near-term field implementation assuming that it passes the safety requirements.

If any additional information would be helpful at this time, please do not hesitate to contact me or John Noland directly.

Very truly yours,

ROY F. WESTON, INC.

John W. Noland
for: Peter J. Marks
Program Manager/
Vice President

/njm

cc: J. Noland

Attachment

INCINERATOR FEED SYSTEM DEVELOPMENT**INTRODUCTION**

The objective of this report is to summarize the background, current status, and proposed testing for the incinerator feed system. The discussion is organized as follows:

- Background
- Current Status of Feed System Development
- Planned Development/Testing Activities

BACKGROUND

The incinerator feed system development was initiated in September of 1982 under WESTON's Task Order No. 2 which involved the actual field demonstration of a pilot scale incineration system for explosives contaminated soils. At the outset of Task Order No. 2, WESTON recommended a screw conveyor feed system for the pilot incinerator. The basis for this recommendation was as follows:

- 1) The screw conveyor represented a relatively low cost feed system suitable for the wide range of soil characteristics anticipated.
- 2) The incinerator subcontractor had a screw conveyor feeder readily available that was suitably sized for the testing.
- 3) The screw conveyor feed system would allow the maintenance of a relatively constant and continuous feedrate which would provide more favorable heat release characteristics than an intermittent bulk feed system.

Soil reactivity testing and a screw conveyor feed system design review was performed by Allegany Ballistics Laboratory (ABL). As a result of this testing and review, ABL determined that the proposed screw conveyor was not acceptable for this application. ABL's report (dated 13 April 1982) made the following statements:

. . . In the reference letter, it was stated that a screw feeder may be used to feed the sample material into an incinerator. There are potential problems associated with using this type of equipment with sensitive materials. In operation of the screw feeder, there are several opportunities for frictional stimuli to occur such as: (1) the flights rubbing the interior wall if the shaft deflects or is misaligned, or (2) if metallic foreign material rubs between the flights and the wall . . .

. . . Another disadvantage is the confinement in the feeder which is undesirable with a potentially explosive feed material . . .

. . . More definitive recommendations could be made and the potential hazards better defined if the entire system were to be considered with respect to reducing risks . . .

Subsequent discussions with ABL revealed that the major concern that they had related to the cantilever shaft design (i.e., the end of the screw conveyor shaft penetrating into the kiln was not bearing supported). This design allowed the potential for metal-to-metal contact. This situation was further aggravated by the fact that the shaft and housing were both ferrous metal (i.e., potential sparking) and that the conveyor tip speed was relatively high. ABL felt that the design could be modified to potentially minimize the risks. However, it was decided by USATHAMA that for the pilot testing an alternative feed system would be developed that would meet the objectives of the testing program and completely avoid these risks. History has shown this to be a prudent decision. WESTON and the incinerator subcontractor developed a bucket feed system that met all test objectives and safety requirements. During the course of the testing program, the feed system cycled over 4,000 times without a single failure.

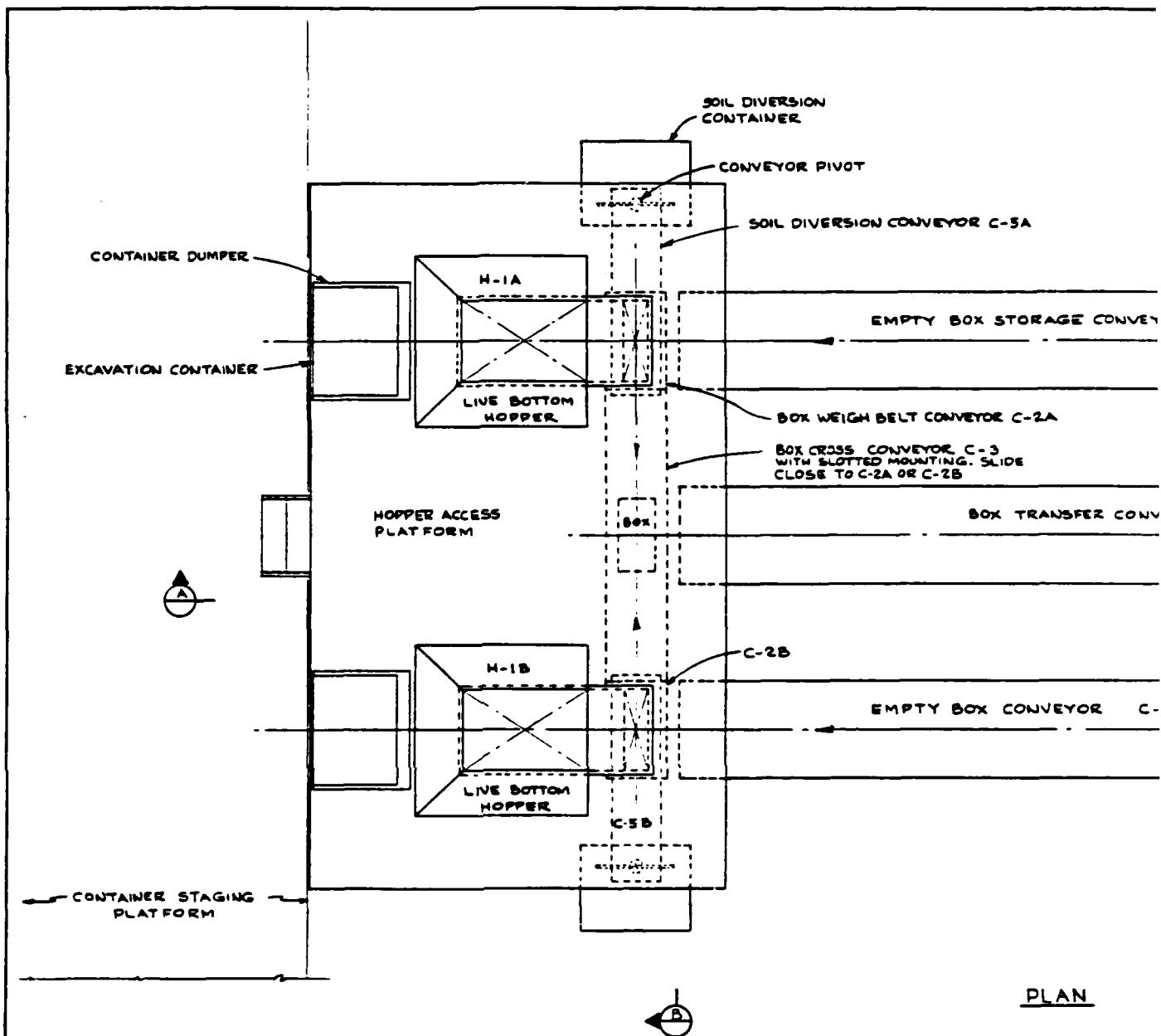
CURRENT STATUS OF FEED SYSTEM DEVELOPMENT

Task Order No. 9 - Feed System Design for Explosives Contaminated Sludge was initiated in June of 1984. Under Task Order No. 9 WESTON evaluated alternative feed systems. The primary criteria for the feed system evaluation was as follows:

- 1) No propagation of flame and/or detonation.
- 2) Operational dependability (high availability and reliability).

- 3) No initiating forces that would potentially result in the functioning of the feed material.
- 4) Low capital and operating costs.
- 5) System that could be ready for field implementation in FY 1986.

As a result of this evaluation, WESTON recommended proceeding with the design of a containerized (i.e., polyethylene-lined cardboard box) feed system which represents the safest and most expedient design for near-term field implementation. However, this system has the disadvantages of relatively high capital and operating costs and a degree of complexity that may result in relatively low operational dependability. Figures 1 and 2 provide overall plan and sectional views of the containerized feed system, respectively.



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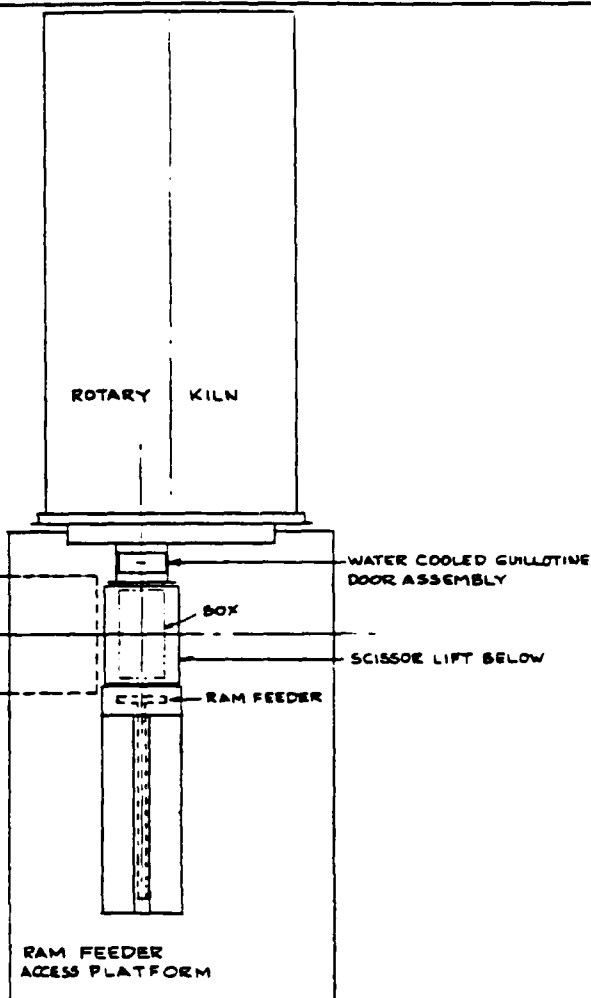
ORAGE CONVEYOR C-1A

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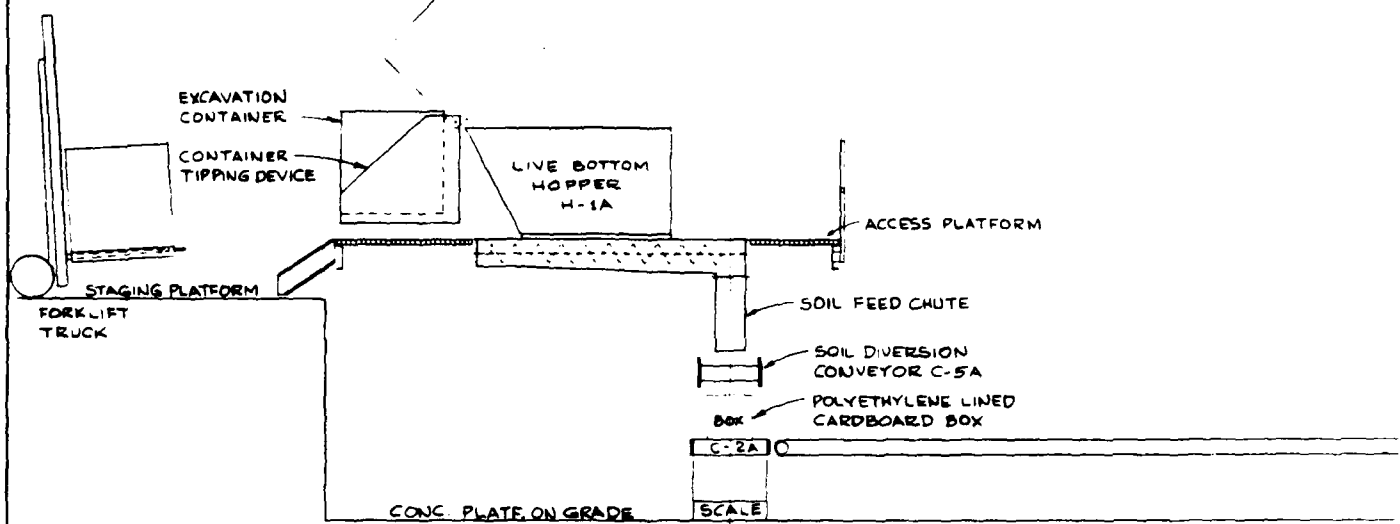
TRANSFER CONVEYOR C-4

CONVEYOR C-1B

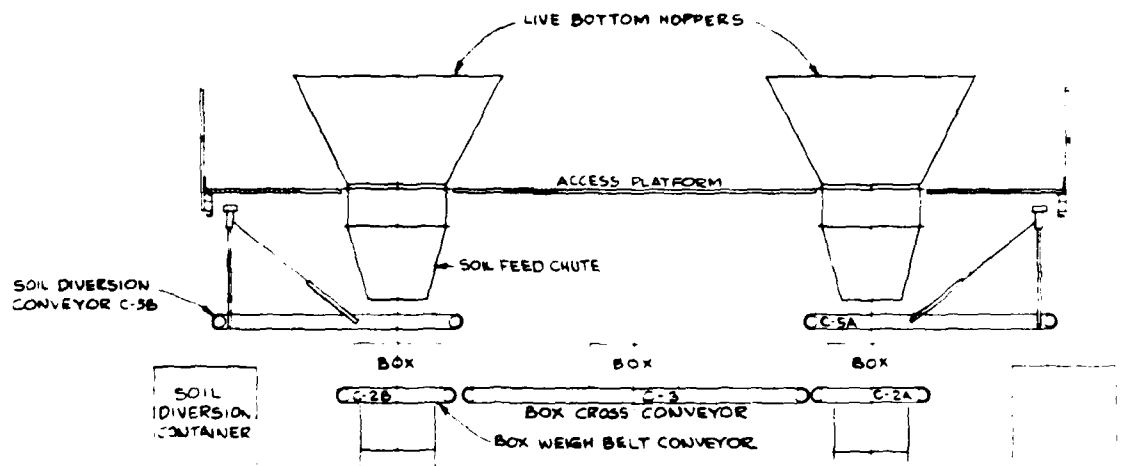
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USATHAMA		DESIGNED BY	DATE	CHECKED BY	DATE	A-5	INCINERATION SYSTEM FOR EXPLOSIVES CONTAMINATED SOILS AND SEDIMENTS			
ON GROUND		DESIGNED BY	DATE	CHECKED BY	DATE		DESIGNED BY	DATE	CHECKED BY	DATE
EDGEWOOD AREA AND		DESIGNED BY	DATE	CHECKED BY	DATE		DESIGNED BY	DATE	CHECKED BY	DATE
WESTON		DESIGNED BY	DATE	CHECKED BY	DATE		DESIGNED BY	DATE	CHECKED BY	DATE
ON GROUND		DESIGNED BY	DATE	CHECKED BY	DATE		DESIGNED BY	DATE	CHECKED BY	DATE



SECTION



SECTION B-B

		USATF	
		ABERDEEN PROVING GROUND	
		WEST	
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GUILLOTINE
DOOR ASSY

ROTARY
KILN

BOX TRANSFER CONVEYOR C-4

BOX SCISSOR LIFT
WITH VERTICAL
GUIDE RAILS

SECTION 'A-A'

RAM FEEDER

Box

ROTARY KILN
PRIMARY CHAMBER

Box

BOX SCISSOR LIFT

SECTION 'C-C'

USATHAMA

GROUND

EDGEWOOD AREA, MD

WESTON

REV.	DATE	BY	CHKD.
1	11/11/88	WJH	WJH
2	11/11/88	WJH	WJH
3	11/11/88	WJH	WJH
4	11/11/88	WJH	WJH
5	11/11/88	WJH	WJH

INCINERATION SYSTEM FOR EXPLOSIVES
CONTAMINATED SOILS AND SEDIMENTS

FIGURE 2

228 01 06

WESTON further recommended the conceptual design of two other alternative feed systems:

- 1) Helical feeder (see Figure 3).
- 2) Reusable bucket feeder (see Figure 4).

Both of these alternative systems offer the potential of lower capital and operating costs relative to the containerized feed system. However, they also present their own potential design problems that would require engineering, field demonstration, and thorough safety review.

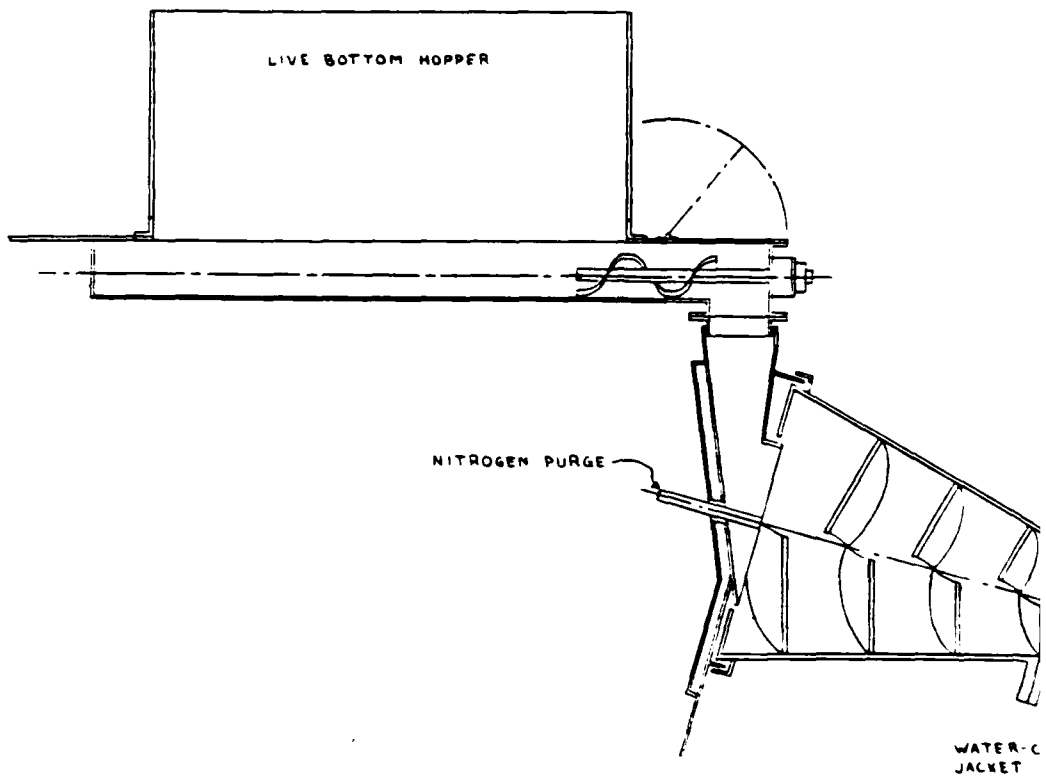
WESTON still strongly favors the screw conveyor feed system concept. However, we are unable to recommend this concept until certain key safety issues are addressed:

- 1) What is the potential for the propagation of flame and/or detonation.
- 2) Can a system be designed that precludes initiating forces that would potentially result in the functioning of the material.

If these two issues can be resolved satisfactorily, WESTON feels that a screw conveyor feed system would be the system of choice for near-term field implementation.

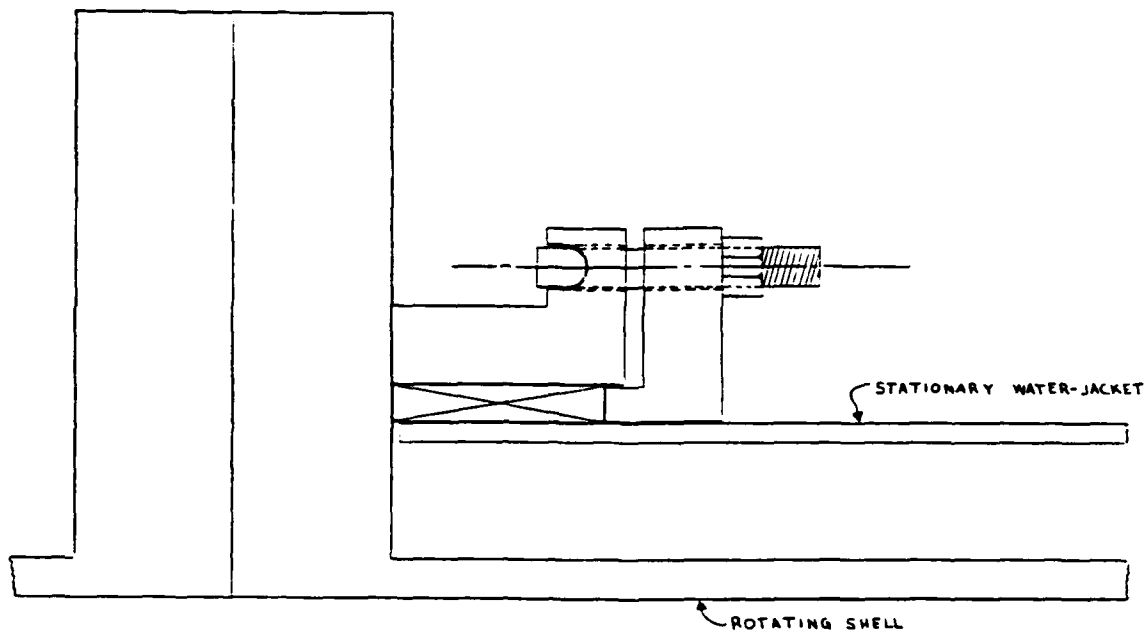
As a result of the current Task Order No. 9 activities, USATHAMA has decided to proceed as follows:

- 1) Complete documentation of the containerized feed system design so that it is available for near-term RFP performance specifications for remedial action projects.

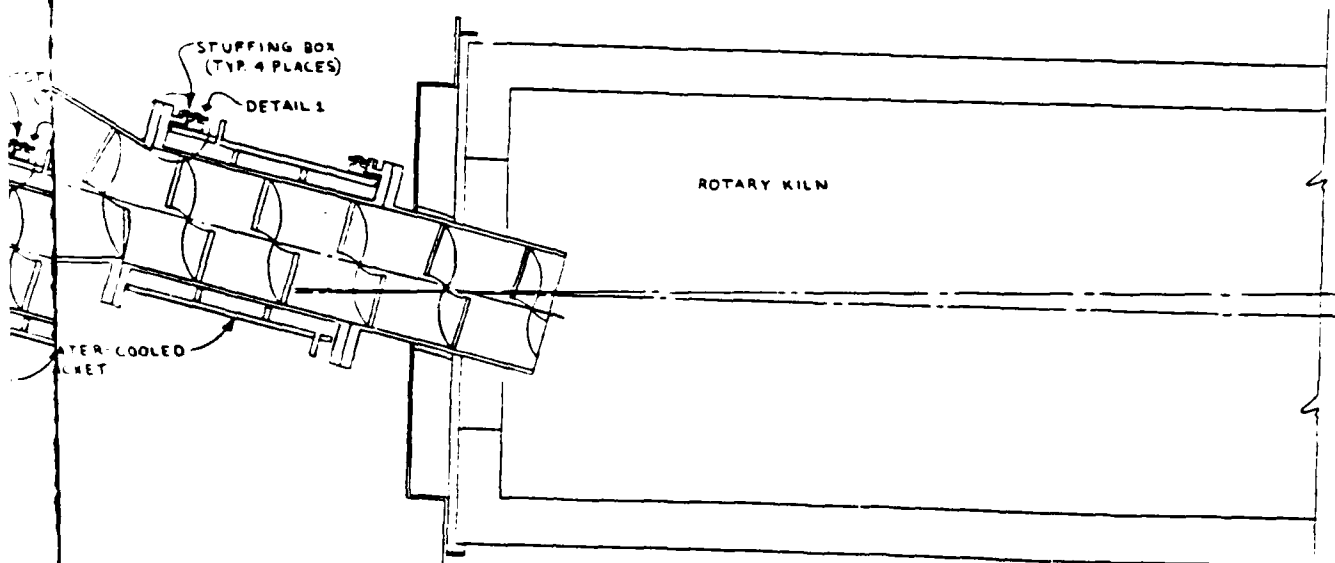


SECTION A-A
SCALE: 3/4" = 1'-0"

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DETAIL 1
FULL SCALE



USATHAMA		DESIGNED	DATE	CHECKED	DATE	CONCEPTUAL DESIGN OF HELICAL FEEDER	
EDGEWOOD AREA MD		DRAWN				A-8	
WESTON		PROJ. ENG.				DESIGNED	
OF ENGINEER		APPROVED				DATE	
DESIGNED BY		APPROVED BY				DATE	
2281-01-08		2-7-85		FIGURE 3		0	

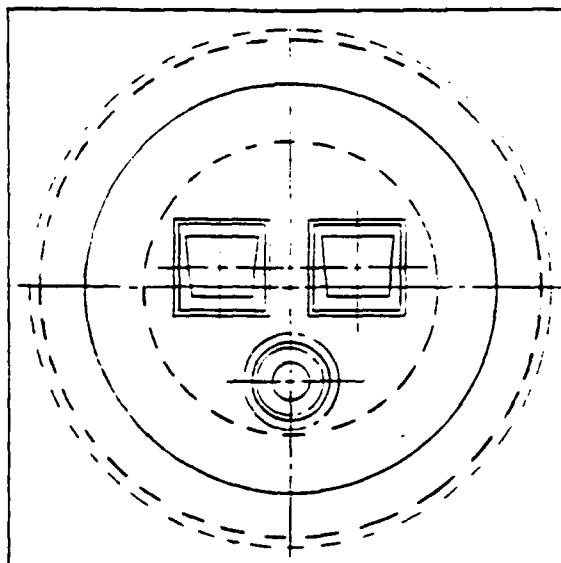
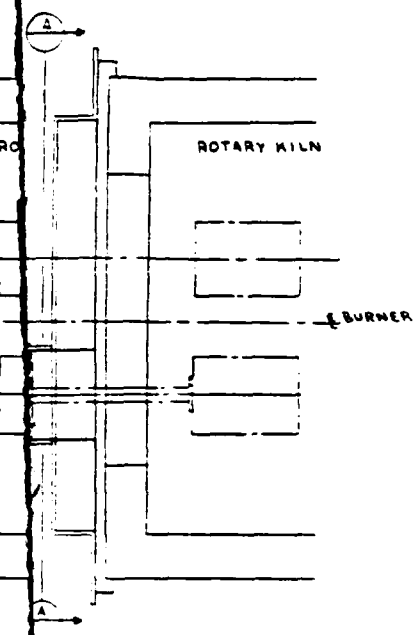


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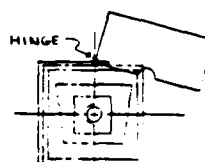
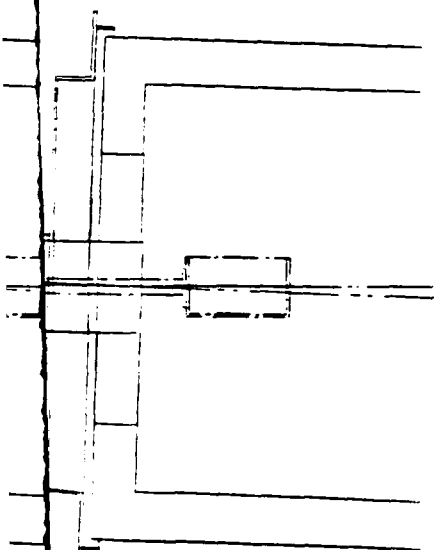
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SECTION A-A



SECTION B-B

USATHAMA MOVING GROUND EDGEWOOD AREA MD		DESIGNED DATE CHECKED DATE APPROVED DATE	CLIENT APPROVALS DATE REBID FOR DATE	A-9	CONCEPTUAL DESIGN OF REUSEABLE BUCKET FEEDER			
WESTON <small>DESIGNERS</small> <small>CONSULTANTS</small> <small>ENGINEERS & ARCHITECTS</small>					DRAWN C S A	DATE 11-28-85	SHEET NO. 2281-01-05	FIGURE 4

- 2) Hold further conceptual design work on the helical feeder and reusable bucket feeder. This work may be continued at a later date if it is determined that a "second generation" feed system is needed.
- 3) Proceed with propagation testing, flame testing, safety evaluation and field demonstration of the screw conveyor feed system.

PLANNED DEVELOPMENT/TESTING ACTIVITIES

In order to accomplish Item (3) above the following development/testing activities are planned:

- 1) Excavate explosives contaminated soils from Louisiana Army Ammunition Plant (LAAP), Cornhusker Army Ammunition Plant (CAAP), and Savanna Army Depot Activity (SADA) and transport to Los Alamos National Laboratory (LANL).
- 2) Perform propagation tests on soil samples from each installation under the following conditions:
 - a) Air dried samples.
 - b) Air dried samples spiked with additional explosives at predetermined increments until propagation occurs.
 - c) Air dried samples with fuel oil added (approximately 15% No. 2 fuel oil and 15% No. 6 fuel oil).
- 3) Perform flame tests on an actual screw conveyor system. The flame tests will include exposing the feed end of the screw conveyor to both open flame and radiant heat simulating the primary chamber (rotary kiln) conditions. This testing would also be repeated for the combination of samples listed above in Item (2).
- 4) Design and fabrication of a full-scale feed system (consisting of a live bottom hopper and screw conveyor feeder) and delivery to LANL for full safety review. ABL would also be subcontracted to assist in this review. Design problems will be evaluated and corrected (where practical) in a good faith effort to develop a safe and operational feed system.

- 5) Field testing of the complete feed system as modified in Item (4) above at SADA and LAAP on actual explosives contaminated lagoon soils.

APPENDIX B

TESTS FOR PROPAGATION OF EXPLOSIONS IN
EXPLOSIVES-CONTAMINATED LAGOON SOILS

0492B

FINAL REPORT

**TESTS FOR PROPAGATION OF EXPLOSIONS
IN EXPLOSIVES-CONTAMINATED LAGOON SOILS**

**LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87544**

LARRY A. STRETZ

MAY, 1986

TESTS FOR PROPAGATION OF EXPLOSIONS IN EXPLOSIVES-CONTAMINATED LAGOON SOILS

INTRODUCTION

This work was done in support of Martin-Marietta Energy Systems, Inc., Oak Ridge National Laboratory (MMES); the US Army Toxic and Hazardous Materials Agency (USATHAMA); and Roy F. Weston, Inc. (Weston). In an overall program to develop an incineration system for the treatment of lagoon soils contaminated with explosive (HE) materials, the Los Alamos effort consisted of two parts. The first was to determine if the contaminated soils would propagate an explosive event through piping of diameters proposed for use in the incinerator feed system. The second part was to investigate the potential for fire or explosion to occur in the feed system due to exposure to the incinerator environment.

The purpose of the tests done at Los Alamos was to provide data for the evaluation of safety aspects concerning the feed-system design for the proposed incinerator.

TEST PLAN

A test plan for the Los Alamos effort in this program was written by Weston and provided through MMES. The stated objectives of the test plan were:

1. Provide standard propagation-test data for the lagoon soils, which can be interpreted readily by the US Army safety community.
2. Perform the standard propagation tests under the following conditions to maximize the usefulness of the data:
 - a. Test lagoon soils from three separate US Army installations [Louisiana Army Ammunition Plant (LAAP), Cornhusker Army Ammunition Plant (CAAP), and Savanna Army Depot Activity (SADA)].
 - b. Conduct all tests with air-dried samples as a "worst case".
 - c. Investigate the effect of alternative pipe diameters, specifically 4-, 5-, and 6-in. diam pipes.
 - d. Increase concentrations of HE in soil incrementally until propagation of explosive reaction occurs.

- e. Investigate the effect of addition of No. 2 fuel oil to the lagoon soil.
3. Simulate the screw conveyor in a propagation-of-reaction test to more closely represent the potential for an event in the actual use of the screw-conveyor feed system.
4. Perform flame testing of a prototype screw-conveyor feed system to investigate the potential for fire/detonation during the actual use of the screw conveyor feed system under "worst-case" upset conditions such as loss of power and coolant flow.

The original test plan was modified in a letter from USATHAMA (Appendix A). The main changes were to provide for testing soils that did propagate an explosive event in 6-in.-diam pipe with added water and to modify the configuration to be flame-tested at incinerator conditions. It was decided at a later time to delete the testing of fuel-oil treated soils. The propagation test on a simulated conveyor was deleted because the conceptual design of the incinerator feed system was changed. Additional changes to the test plan, resulting from evolution of the feed-system design, were verbally agreed to by all interested parties. These changes are reflected in a separate report on the flame test--design and results.

TESTING AND RESULTS

For clarity, the tests and results are presented in the following sections: Soil Preparation and Analysis, Soil Propagation Tests (including "Blanks", SADA Soil Propagation Tests, CAAP Soil Propagation Tests, and LAAP Soil Propagation Tests), and Propagation Test Summary.

Soil Preparation and Analysis

All soil samples were received at Los Alamos in 5-gal. plastic pails. The contents as received were saturated with water with additional water standing on top of the soil.

The soil samples from the three facilities were handled in the same manner. Detail on the preparation of the LAAP soil is presented as typical. All pails containing LAAP soil samples were emptied into plastic-lined drying troughs where excess water was allowed to evaporate. The material was hand turned and mixed to facilitate drying; even so, it took several days. During this period, the sample was visually inspected for evidence of HE. When the moisture content dropped to less than 8 wt%, the material was divided into portions (no. 1-21) for blending to provide as homogeneous a sample as possible. The blending was done as depicted in Table I where Level is the number of blending operations the sample has been

through, the Sample-portion designations identify individual fractions of the total sample, and Blend describes the combination of sample portions to result in the next blend level. For example, 21 unique Sample Portions are assumed to be unmixed at Level 0. These are blended by combining Portions 1, 2, and 3 to result in three identical Portions (designated as 1) at Level 1; combining Portions 4, 5, and 6 to give three Portions (designated 2) at Level 1; and so on, resulting in seven unique blends at the completion of Level 1. Portions from Level 1 are recombined as shown in Table I so, at the completion of Level 2 there are only three unique blends of soil. These are then recombined again to give a blended sample, all Portions having the same blend history. A sample of the blended material was submitted to the analytical laboratory for determination of HE content. Results of the visual inspection and analysis are given in Table II.

Soil Propagation Tests

All propagation tests were conducted using the standard setup shown in Figure 1, which was copied from the original Weston test plan. For the purpose of these tests, we assumed that an explosive reaction would somehow be initiated in the material. The question was then "will the reaction propagate through the material in 4-, 5-, or 6-in. diam pipes?" This testing in no way relates to the probability of initiation in such a feed system. The question of whether or not the material is likely to initiate in the feed system was not addressed in this study.

Blanks. To evaluate the test results from all soil samples, several tests were conducted on "blanks" consisting of the standard test setup filled with uncontaminated soil. In all cases, the shots on blank samples resulted in undamaged witness plates and pipes either in large sections or incompletely split. These results were used to gauge the response of HE-contaminated samples in subsequent testing.

SADA Soil Propagation Tests. The SADA soil samples were air dried, blended, and returned to the shipping containers in preparation for propagation testing. Moisture content was determined by weight loss upon heating in a forced-draft oven at 70°C until no additional weight loss occurred during a one-hour period. The moisture content was determined to be 4.55 wt%.

The first test shot was done with a 4-in.-diam test setup filled with unpacked soil. The witness plate was undamaged and the pipe was not completely split. This was followed by six shots on 6-in. diam test setups. In all these tests, the witness plates were undamaged and the pipes survived in large sections with the top portions peeled back.

The conclusion from these tests is that SADA air-dried samples will not propagate an explosive event in stainless-steel pipes with diameters smaller than six-inches.

TABLE I
SAMPLE BLENDING

Level and Action	Sample Portion																				
Level 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Blend to give Level 1	1+2+3			4+5+6			7+8+9			10+11+12			13+14+15			16+17+18			19+20+21		
Level 1	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7
Blend to give Level 2	1+2+3			1+2+3			1+2+3			4 +5 +6			4 +5 +6			4 +5 +6			none		
Level 2	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B	B	7	7	7
Blend to give Level 3	A+B+(1/3)7 (9 total blends)																				
Level 3	21 pails containing "uniform blended sample".																				

TABLE II
SAMPLE INSPECTION AND ANALYSIS

Sample ID	Visual Inspection	Bulk Density (g/cm^3)	HE content (wt%)	TNT/RDX ^a ratio
SADA	Sandy, no visible HE	1.08	4.6	all TNT
CAAP	Gummy, no visible HE	1.10	5.4	2.4:1
LAAP	Sand/Clay, chunks of TNT	0.93	44.2	3.3:1

^aRDX includes some HMX.

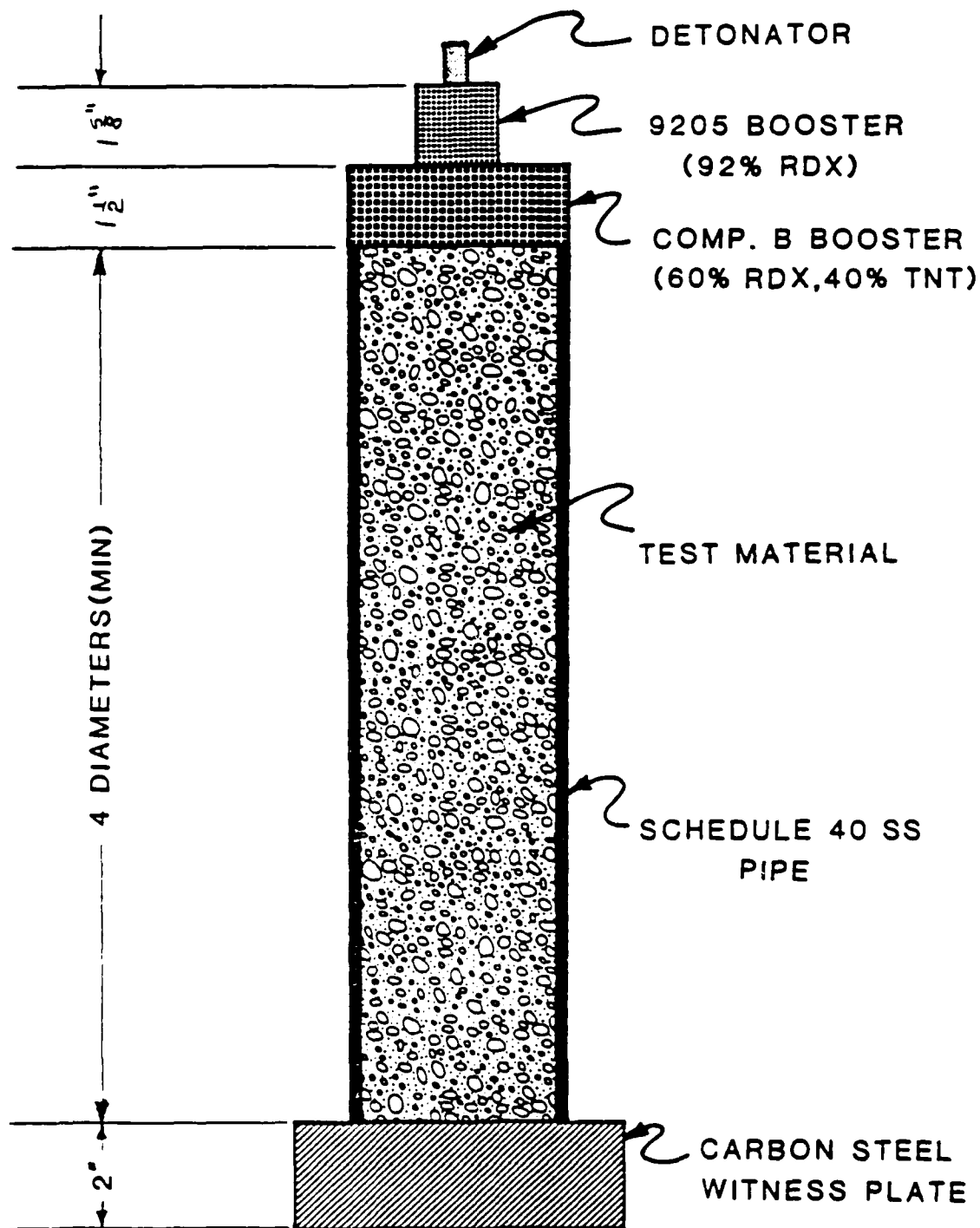


Figure 1. Typical Propagation Test Setup

Following the NoGo results with the as-received SADA material, several samples were spiked with various amounts of TNT. The samples were prepared by dissolving a known amount of TNT in acetone and adding this to the air-dried soil. The acetone was then allowed to evaporate, leaving a spiked sample with the TNT distributed throughout the material. The first SADA spiked test was done with an added HE loading to bring the total nominal HE content to 30 wt%. This test produced a Go result, indicated by slight denting of the witness plate and breaking of the pipe into numerous fragments. Although interpreted as a Go, the explosive event was weak. A second spiked sample was run at a nominal 35-wt% HE. This produced a strong dent on the plate and fragmented the pipe. The third loading tested was a nominal 25-wt% HE and produced a very weak dent in the witness plate, probably resulting from shock traveling down the walls of the pipe rather than from a propagating explosion. The center of the plate was not dented and the pipe, while completely fragmented, was in larger pieces than those from the 30-wt% test. This result was interpreted as a NoGo but the test was repeated to verify this conclusion; in this repeated test, the plate was undented and pipe was broken into several pieces - those from the bottom of the pipe were large and a NoGo interpretation was quite clear. The results of the spiked samples indicate that explosive reactions could propagate in air-dried SADA soil with a loading of 25 wt% or more TNT.

CAAP Soil Propagation Tests. The CAAP soil samples were dried, blended, and returned to the shipping containers. Several lumps of material were removed and analyzed but were found not to be HE. Representative samples of the bulk material were analyzed and found to contain both TNT and nitramines (HMX and RDX) in a ratio of about 2.4:1 TNT:nitramine. Moisture content, measured in the same manner as for the SADA samples, was 6.82 wt%.

A sample of the CAAP soil was loaded into a 6-in.-diam test setup, then the shot was fired. The witness plate was undamaged and the pipe was peeled open for only about half its total length. A portion of the original sample was compressed into a cake in the bottom section of the test pipe. This test was repeated five times with the same result in each case. The tests clearly indicate that an explosive event does not propagate in the CAAP soil in 6-in. diam stainless-steel pipes.

As with the SADA tests, the CAAP soil was spiked and tested with additional HE. The spiking was done in the same manner, with RDX added to maintain the TNT:nitramine ratio found in the original material. The first spiked test was fired with a nominal HE loading of 35 wt%. The pipe was recovered in large pieces but there was a slight dent in the witness plate. This must be interpreted as a Go, even though the explosive reaction was weak. The second spiked test on CAAP soil was at a nominal 30-wt% HE and resulted in a NoGo. A slight dent was observed on the witness plate in the ring where the pipe was in contact with the plate, but there was no dent in the center of the plate. The pipe itself had broken into large pieces,

some them as long as the test piece. A third spiked test was fired with a nominal 25-wt% HE loading and gave an undamaged witness plate and a pipe peeled open but not completely split. These results indicate that CAAP soil will propagate an explosive event at HE loadings above 30 wt% and is marginal in the 25 to 30-wt% range.

LAAP Soil Propagation Tests. The LAAP soil was air-dried, blended, and returned to the shipping containers. A blended sample was removed for analysis as were several large pieces of crystalline material that appeared to be TNT. Subsequent analyses confirmed that the material was TNT, and the bulk sample showed a TNT:nitramine ratio of 3.3:1 with a total HE content of 44.2 wt%. Moisture content, determined as with the SADA and CAAP soils, was found to be 5.92 wt%.

A sample of the LAAP soil was loaded into a 6-in.-diam test setup and fired. The material propagated the detonation, giving a strong dent in the witness plate and fragmenting the pipe. A second test was fired at 6-in.-diam and a third in a 4-in.-diam setup. Propagation was clearly indicated in all cases. By the original test plan, this completed the LAAP testing; but subsequent discussions with MMES, USATHAMA, and Weston led to modification of the original test plan to include tests with water added to the soil.

In compliance with the revised test plan, a 4-in.-diam setup was filled with LAAP air-dried soil with 10-wt% water added. The result was a NoGo, with mud plastered on the undamaged witness plate and pipe peeled back but not completely split. The shot was repeated with essentially the same result. In the second shot, the pipe was in three major pieces and split end to end. The water addition was reduced to 5 wt% in yet another 4-in.-diam test. This resulted in a Go, indicated by more and smaller pipe fragments and a dent in the witness plate.

With the success of preventing propagation in 4-in.-diam pipes by adding 10-wt% water to the LAAP soil, we decided to try a 6-in.-diam test with the same mixture. Filling the 6-in.-diam setup required 26.5 pounds of soil plus the 2.65 pounds of added water. The shot was fired and resulted in a Go with the pipe fragmented and the plate dented. Another 6-in.-diam setup was filled with LAAP soil and 15 wt% water. With the additional water, the soil stuck together and packed more tightly as it was poured into the pipe. Filling the pipe required 29 pounds of soil plus the added water. The result of the shot was a deep dent in the witness plate and fragmentation of the pipe into small pieces. The water was then increased to 20 wt%, which required 36 pounds of soil plus the water to fill the 6-in.-diam test setup. The soil/water mixture was a thick slurry, almost like wet cement with this amount of water. This slurry could be poured into the pipe and, if left to settle, a pool of free water would form on the surface. Firing this shot resulted in very small fragments from the pipe and a witness plate that was deeply dented, distorted on the edges, with small cracks visible on the back side.

Obviously, the water addition will not prevent propagation in this LAAP soil in 6-in.-diam pipes without going to a very dilute slurry. Addition of water resulted in closer packing of the soil and an appreciably higher volume-percent HE content. The presence of water may make it more difficult to initiate the HE in the soil, but, at the levels tested, does result in a mixture that is more likely to propagate once initiated.

Comparable to the spiking of the SADA and CAAP soils with additional HE, several tests were run with LAAP soil diluted with clean sand. To conserve material, the first such test was run in a 4-in.-diam test setup with sand added to give a nominal 25-wt% HE loading in the sample. The result was a NoGo, with an undamaged witness plate and the pipe split into three major pieces. Another 4-in.-diam test was fired with a nominal 35-wt% HE loading and resulted in a marginal Go with a slight dent in the plate and the pipe fragmented into large pieces. With these two tests as a guide, a 6-in.-diam setup was loaded with a LAAP/sand mixture at a nominal 35-wt% HE loading. The test was fired and resulted in a dented plate and fragmented pipe; the dent was not deep but was clearly an indication of propagation. The next 6-in.-diam shot was fired with a nominal 25-wt% HE loading and resulted in a clear NoGo; the witness plate was undamaged and the pipe was not completely split. The last confined LAAP shot was done in a 6-in.-diam setup with soil cut with sand to a nominal 30-wt% HE loading; it gave a marginal Go with a slight dent in the plate and large fragments from the pipe.

Following the confined testing with the LAAP soil, two tests were conducted with a 6-in.-diam setup in which the stainless steel pipe was replaced by a tube of 10-mil-thick polyethylene, making this essentially an unconfined test of propagation. This configuration was loaded with the air-dried LAAP soil and fired. The witness plates were dented in both shots, indicating that the material will propagate unconfined at 6-in.-diam.

Propagation-Test Summary

All propagation tests are summarized in Table III. The as-received and air-dried SADA and CAAP samples will not propagate a detonation or explosive reaction in 6-in.-diam stainless-steel pipe. The LAAP soil will propagate in 4-in.-diam and/or larger pipe. Diameters smaller than four inches were not tested.

All three soils were tested with either HE or clean sand added to determine at what HE loading propagation would occur in 6-in.-diam pipes. In all three cases, there was evidence of propagation at nominal loadings of 30 to 35-wt% HE but not at 25-wt% HE content.

Water addition did not prove effective in preventing propagation of reaction in the LAAP sample in a 6-in.-diam pipe. In fact, due to better packing when water is added to the soil, the volume-percent HE in the pipes actually increased, which enhanced propagation. The

LAAP soil was also found to propagate a detonation or explosive reaction in 6-in.-diam when unconfined.

Appendix B to this report contains the photographs taken before and after the tests. They include the test setup, sampled soils, and after-test pipes and witness plates.

TABLE III
PROPAGATION TEST SUMMARY

<u>Sample</u>	<u>Treatment</u>	<u>Pipe Dia (in.)</u>	<u>No. of Shots</u>	<u>Result</u>	<u>Comments</u>
Blank	No HE	6	1	NoGo	Pipe split
Blank	No HE	6	1	NoGo	
Blank	No HE	4	1	NoGo	
SADA	Air-dried	4	1	NoGo	Weak reaction
SADA	Air-dried	6	6	NoGo	
SADA	Spiked to 35 wt% HE	6	1	Go	
SADA	Spiked to 30 wt% HE	6	1	Go	Weak reaction
SADA	Spiked to 25 wt% HE	6	2	NoGo	
CAAP	Air-dried	6	6	NoGo	
CAAP	Spiked to 35 wt% HE	6	1	Go	Weak reaction
CAAP	Spiked to 30 wt% HE	6	1	NoGo	
CAAP	Spiked to 25 wt% HE	6	1	NoGo	
LAAP	Air-dried	6	2	Go	Unconfined
LAAP	Air-dried	4	1	Go	
LAAP	10 wt% water added	4	2	NoGo	
LAAP	5 wt% water added	4	1	Go	Weak reaction
LAAP	10 wt% water added	6	1	Go	
LAAP	15 wt% water added	6	1	Go	
LAAP	20 wt% water added	6	1	Go	Weak reaction
LAAP	Cut to 25 wt% HE	4	1	NoGo	
LAAP	Cut to 35 wt% HE	4	1	Go	
LAAP	Cut to 35 wt% HE	6	1	Go	Weak reaction
LAAP	Cut to 25 wt% HE	6	1	NoGo	
LAAP	Cut to 30 wt% HE	6	1	Go	
LAAP	Air-dried	6	2	Go	Unconfined

Appendix A

TEST PLAN MODIFICATION

REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
US ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010-5401

June 6, 1985

Technology Division

Mr. Larry Stretz
Los Alamos National Laboratories
Box 1663 MS C920
Los Alamos, New Mexico 87545

Dear Mr. Stretz:

The purpose of this letter is to supplement the test plan prepared by Roy F. Weston, Inc. and submitted to you in March of 1985. In accordance with our verbal discussions on March 14, 1985, please proceed with the propagation testing in the following manner:

a. Once the standard propagation testing is completed for Louisiana Army Ammunition Plant, Savanna Army Depot Activity, and Cornhusker Army Ammunition Plant soils that have been air dried, proceed as follows:

1. For soil types that do not propagate in six-inch diameter pipes (i.e. Savanna Army Depot Activity and Cornhusker Army Ammunition Plant), add explosives in five percent increments to the respective soil until propagation occurs in a six-inch diameter pipe. Explosives should be added in the same basic ratio as present in the contaminated soil (e.g., 5:1 ratio of TNT to RDX, etc.).

2. For soil types that do propagate in six-inch diameter pipes (i.e. Louisiana Army Ammunition Plant), add moisture in five percent increments to the soil until propagation does not occur in a six-inch diameter pipe or until the soil becomes a slurry (whichever occurs first).

b. Perform flame testing using Louisiana Army Ammunition Plant air dried soil. The prototype feed system will be fabricated by Los Alamos National Laboratories in accordance with Section C-C of Drawing No. TU-2 (enclosed). Weston will provide the ribbon flight screws. The tests will be run with a steam purge, a water spray purge, and with no purge for flame suppression. For further details, contact Mr. John Noland of Weston directly.

c. After the flame testing is complete, the following additional propagation testing shall be conducted:

1. Dilute the air dried Louisiana Army Ammunition Plant soil with sand until propagation does not occur in a six-inch diameter pipe.
2. Perform an unconfined propagation test with Louisiana Army Ammunition Plant air dried soil in a thin gauge, six-inch diameter plastic pipe.

Point of contact at this Agency is Mr. Wayne Sisk, (301) 671-2054.

Sincerely,



Wayne E. Sisk
Contracting Officer's
Representative

Enclosure

Copy Furnished (with enclosures):

Mr. John Nolan, Roy F. Weston, Inc., Weston Lane, West Chester, Pennsylvania
19380
Mr. Ted Fox, Oak Ridge National Laboratory, Post Office Box Y, Oak Ridge,
Tennessee 37831

Appendix B

TEST PHOTOGRAPHS

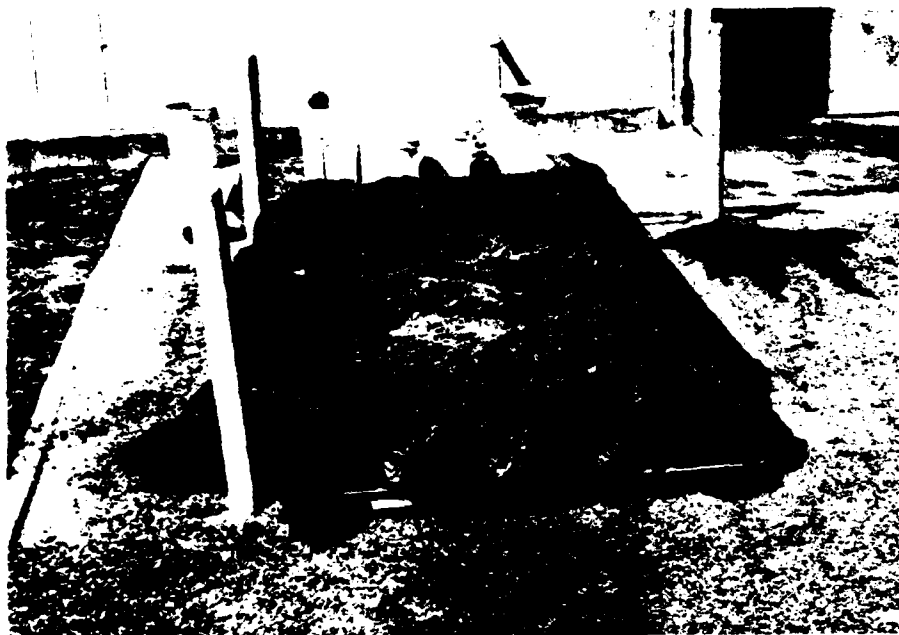


Photo 1. Drying pan with LAAP sample.



Photo 2. Chunks of TNT removed from LAAP sample.

B-3



Photo 3. Typical 6-in.-diam test setup.



Photo 4. Eight-in. by eight-in. witness plate for 6-in.-diam test setup.

B-17

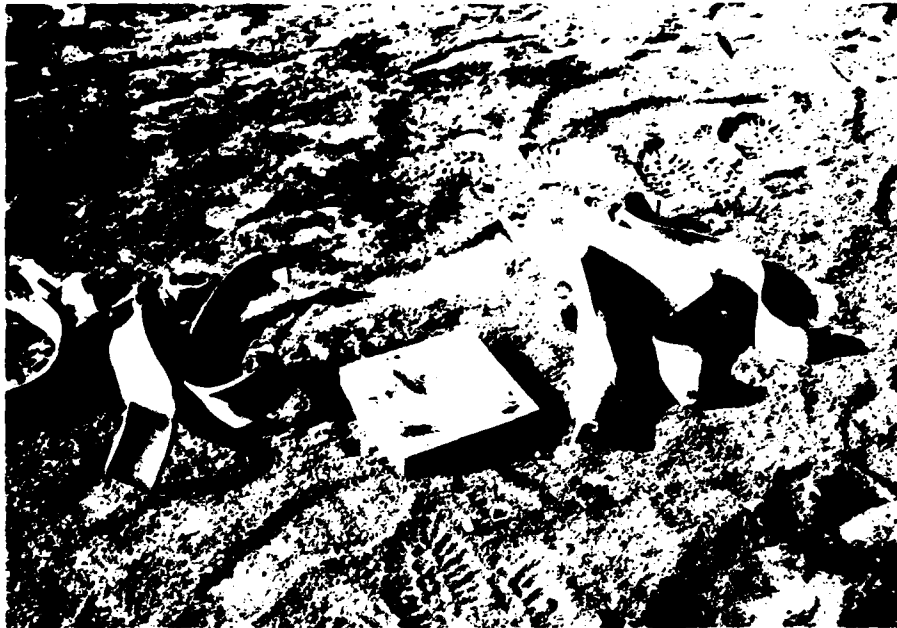


Photo 5. Result of first 6-in.-diam blank shot.



Photo 6. Result of second 6-in.-diam blank shot.



Photo 7. Result of second 6-in.-diam blank shot.



Photo 8. Six-in. by six-in. witness plate for 4-in.-diam test setup.



Photo 9. Witness plate after 4-in.-diam blank shot.



Photo 10. Pipe after 4-in.-diam blank shot.



Photo 11. Result of SADA 4-in.-diam shot.



Photo 12. Result of first SADA 6-in.-diam shot.



Photos 13-17. Results of second through sixth SADA
6-in.-diam shots.

Photo 18. Result of
6-in.-diam shot with
SADA soil spiked to
30 wt% HE content.



Photo 19. Result of
6-in.-diam shot with
SADA soil spiked to
35 wt% HE content.



Photo 20. Result of
6-in.-diam shot with
SADA soil spiked to
25 wt% HE content.





Photos 21-22. Results of first two CAAP 6-in.-diam shots.



Photo 23. Pipe with caked sample after second 6-in.-diam CAAP shot.



Photos 24-27. Results of third through sixth CAAP
6-in.-diam shots.

Photo 28. Result of
6-in.-diam shot with
CAAP soil spiked to
35 wt% HE content.



Photo 29. Result of
6-in.-diam shot with
CAAP soil spiked to
30 wt% HE content.

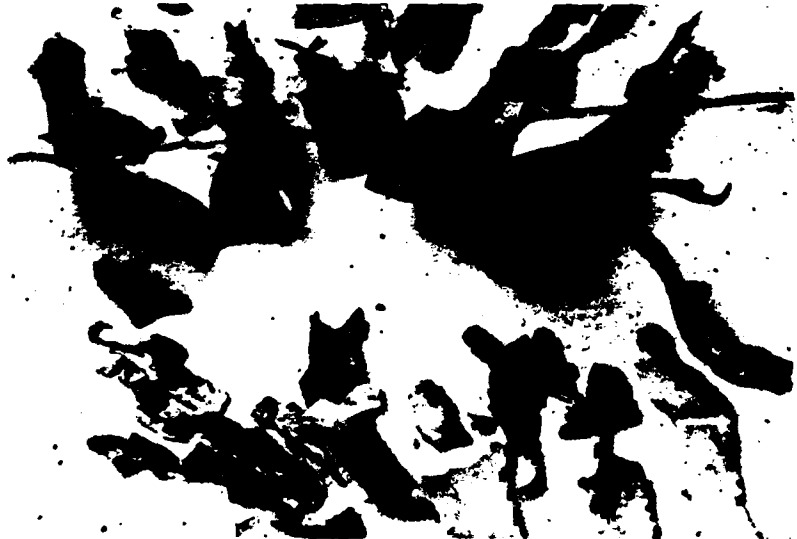


Photo 30. Result of
6-in.-diam shot with
CAAP soil spiked to
25 wt% HE content.

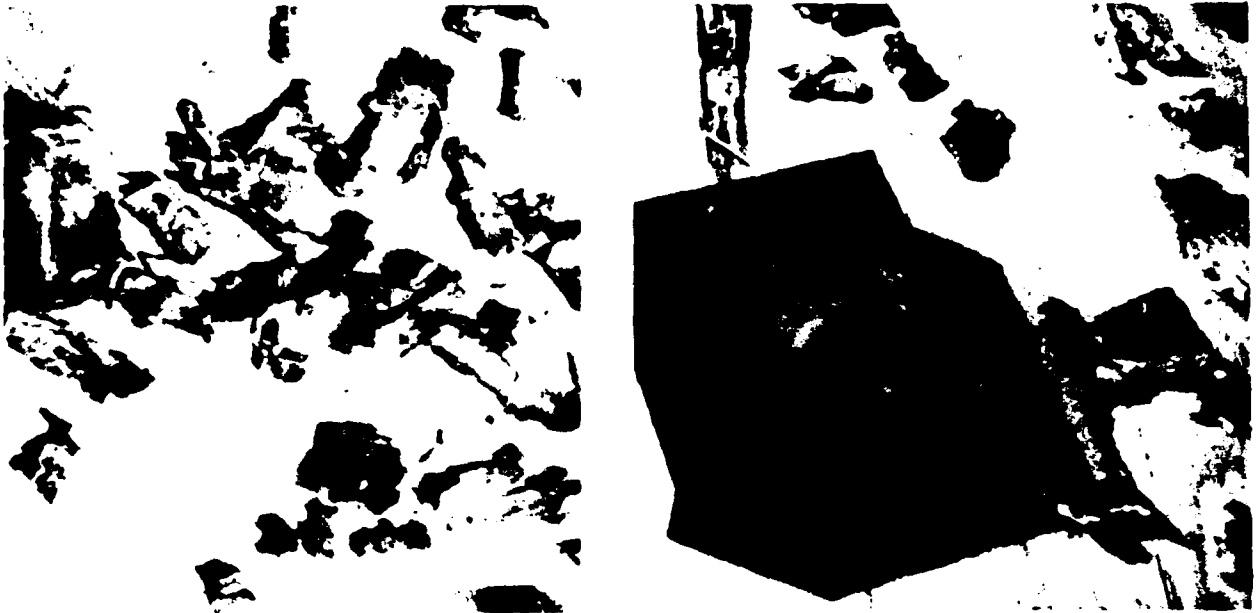




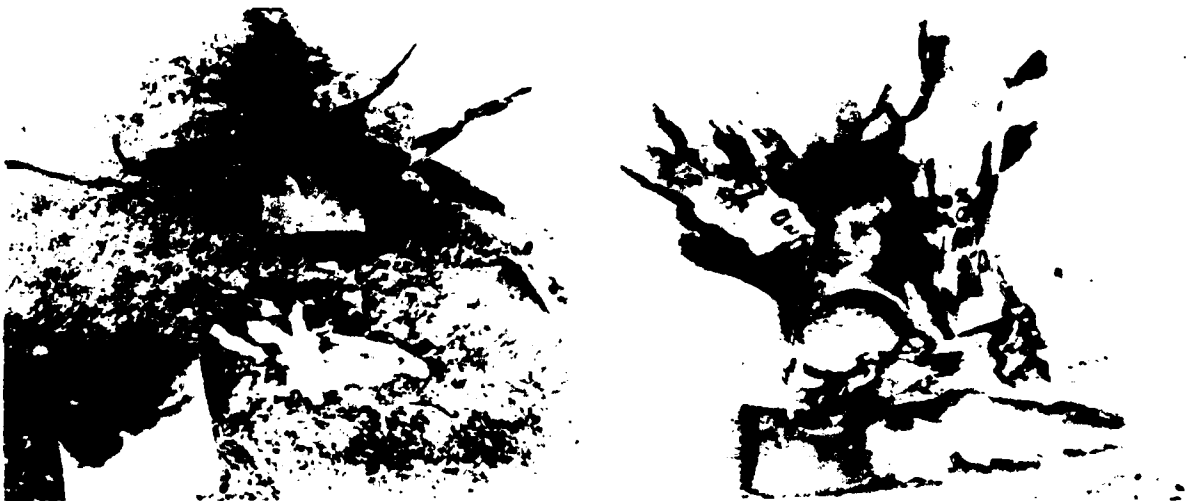
Photos 31-32. Result of first LAAP 6-in.-diam shot.



Photos 33-34. Result of second LAAP 6-in.-diam shot.



Photos 35-36. Result of LAAP 4-in.-diam shot.



Photos 37-38. Results of two 4-in.-diam shots on LAAP soil with 10 wt% water added.



Photo 39. Result of 4-in.-diam shot on
LAAP soil with 5 wt% water added.



Photo 40. Result of 6-in.-diam shot on LAAP soil
with 10 wt% water added.



Photo 41. Result of 6-in.-diam shot on LAAP soil with 15 wt% water added.



Photo 42. Result of 6-in.-diam shot on LAAP soil with 15 wt% water added.



Photo 43. Result of 4-in.-diam test on LAAP soil diluted with clean sand to a nominal 25 wt% HE content.



Photo 44. Result of 4-in.-diam shot on LAAP soil diluted with clean sand to a nominal 25 wt% HE content.



Photo 45. Result of 6-in.-diam shot on LAAP soil diluted with clean sand to a nominal 35 wt% HE content.



Photo 46. Result of 6-in.-diam shot on LAAP soil diluted with clean sand to a nominal 25 wt% HE content.



Photo 47. Result of 6-in.-diam shot on LAAP soil diluted with clean sand to a nominal 30 wt% HE content.

APPENDIX C

FLAME TESTING OF INCINERATOR FEED SYSTEM HANDLING
EXPLOSIVES-CONTAMINATED LAGOON SOILS

0492B

FINAL REPORT

FLAME TESTING OF EXPLOSIVE-CONTAMINATED
LAGOON SOIL

LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545

LONNIE B. CHAPMAN

MARCH, 1986

FLAME TESTING OF EXPLOSIVE-CONTAMINATED LAGOON SOIL

INTRODUCTION

This work is being done in support of Martin-Marietta Energy Systems, Inc., Oak Ridge National Laboratory (MMES) in their work with the US Army Toxic and Hazardous Materials Agency (USATHMA) and Roy F. Weston, Inc. (Weston). The overall program was to develop an incineration system for the treatment of lagoon soils contaminated with energetic materials. The Los Alamos contribution was two-fold; first to determine experimentally if the contaminated soils would propagate an explosion in the pipe diameters proposed for the incinerator feed system; and secondly to observe the results of flame testing the soils using temperatures and feed conditions normally found in an incinerator. This report deals with the second part of this effort.

The flame test's specific purpose was to investigate the potential for fire or detonation during the actual application of the screw-conveyor feed system under "worst-case" conditions, such as, a power failure. High-explosive (HE)-contaminated lagoon soils were exposed to incinerator conditions while confined in a mockup of the proposed twin-screw conveyor. The test was done in conjunction with other propagation tests using a variety of contaminated soils. Soil from the Louisiana Army Ammunition Plant was used for the flame test because it had the greatest potential to burn or detonate.

SYSTEM DESCRIPTION

Conveyor

A mockup conveyor (tray) was built to simulate a worst-case section of the proposed conveyor (Fig. 1). A 3/16-in. (4.76-mm) plate steel tray was built with a 9-in. (0.23-m) square inside cross section. The tray measured

- SAMPLE LOCATION
- THERMOCOUPLE LOCATION

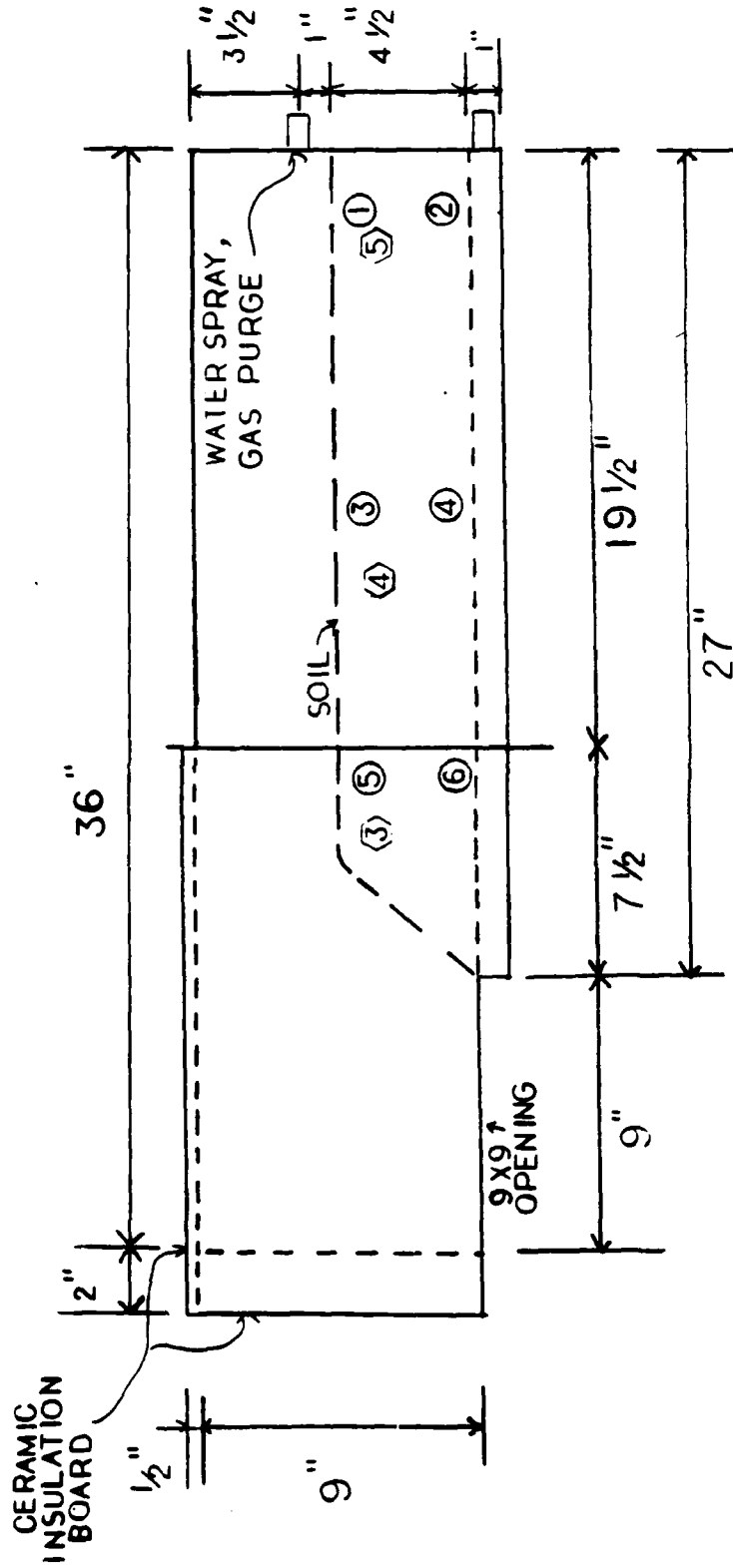
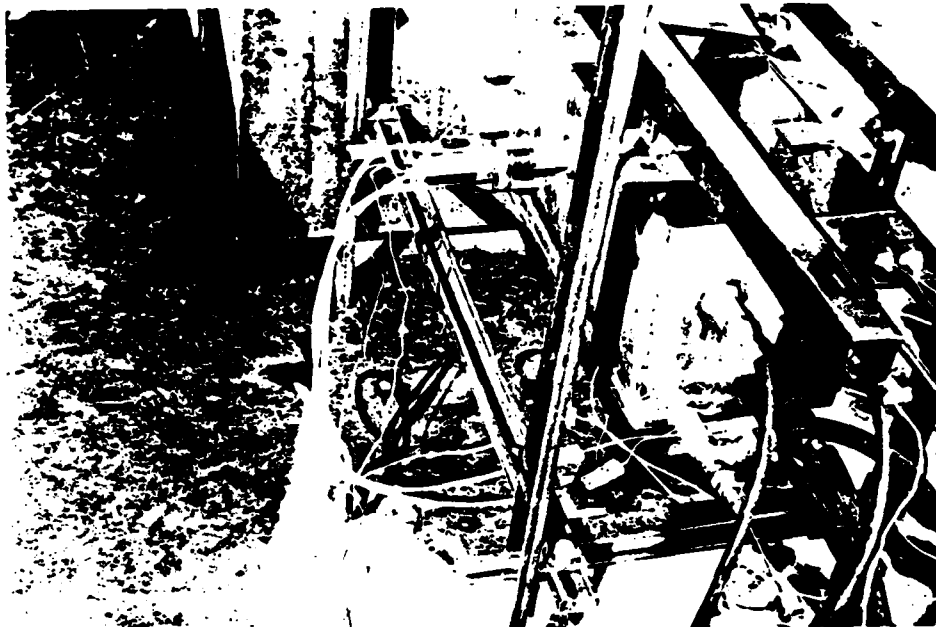


Fig. 1. Prototype conveyor (tray)

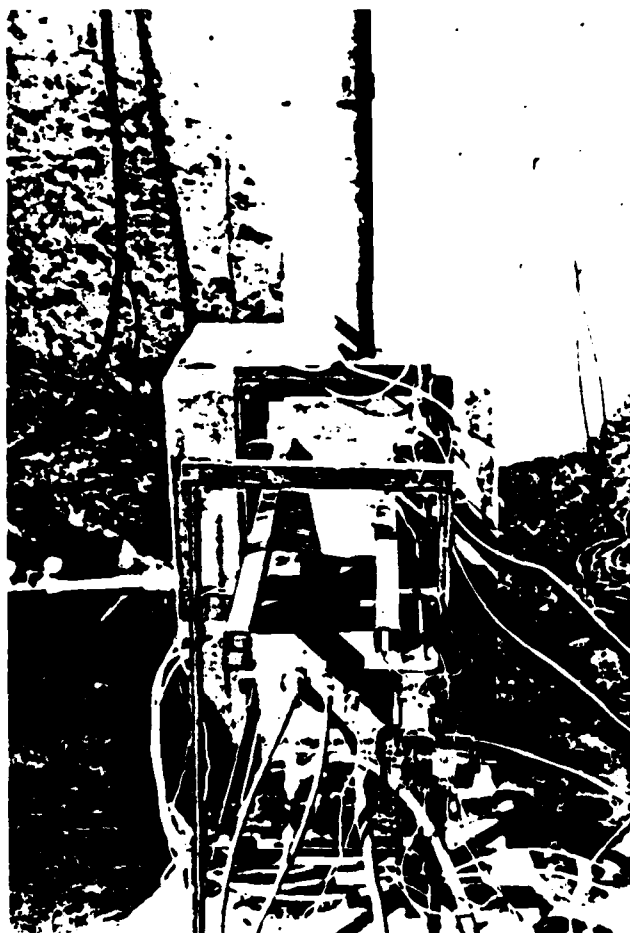
36-in. (0.9-m) long x 9-in. (0.23-m) wide x 9-in. (0.23-m) high. The last 9 in. (0.23 m) toward the firebox had a 9-in. (0.23-m) x 9-in. (0.23-m) opening at the bottom to simulate the conveyor's open end. The remaining 27 in. (0.69 m) of tray bottom were covered with a 1-in. (25.4-mm)-thick water jacket made from the same material as the tray. Inlet and outlet water-jacket connections were made to the tray. Other connections were made for two ultra violet (uv) flame detectors, three thermocouples (TC), inert gas purge, and water spray connections (Fig. 2A and 2B). The remaining unprotected sides were covered with 1/2-in. (12.7-mm)-thick ceramic fiber board to simulate the insulating effect of the additional soil inside the proposed conveyor interior. The tray was installed on a trolley and attached to a reversible motor to allow it to be inserted and removed remotely from the firebox.

Firebox

The skid-mounted firebox, shown in Figs. 3A, 3B, and 4, was fabricated from 3/16-in. (4.76-mm) steel plate and insulated internally with 4 in. (102 mm) of ceramic fiber board. Openings were cut into one end and side of the firebox to insert the tray and burner. The side opposite the tray opening was made removable to allow installation and inspection of the interior insulation. An 8-in. (0.2-m)-diameter hole was cut into the top of the firebox for flue gas escape and an 8-in. (0.2-m)-diam x 4-ft (1.2-m)-long pipe was attached to provide draft. The burner was a 200,000-Btu/h induced-draft-type propane burner with a pilot (Figs. 5A and 5B). Both the firebox and tray were located 400 ft (140 m) from the control room, below a hill and inside a concrete firing-site for the protection of personnel and equipment (Figs. 6A and 6B).



A. Side view.

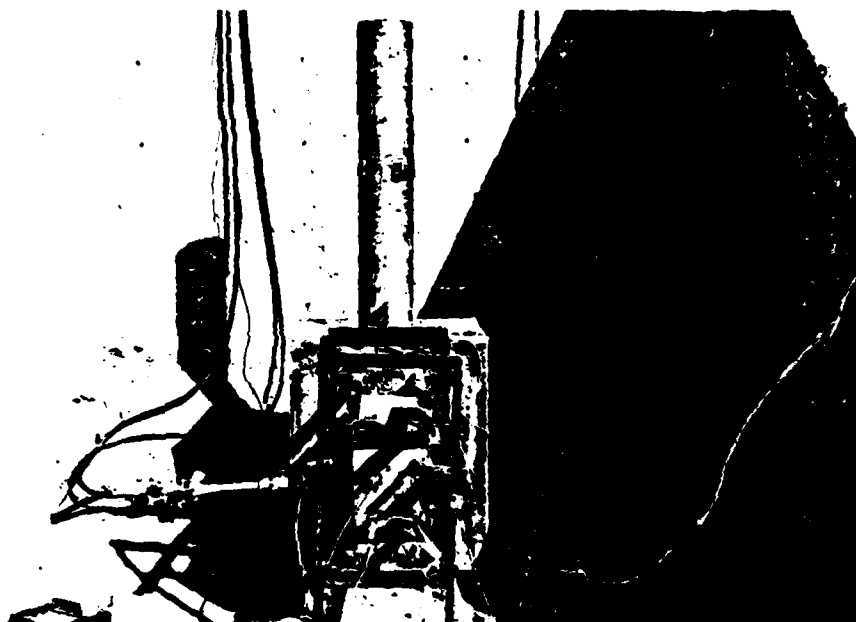


B. End view.

Fig. 2. Side and end views of the tray and tray connections.



A. Side view shows ceramic fiber insulation on the tray (white).



B. End view shows burner and propane hoses in place.

Fig. 3. Tray, trolley and firebox in place with the stack.

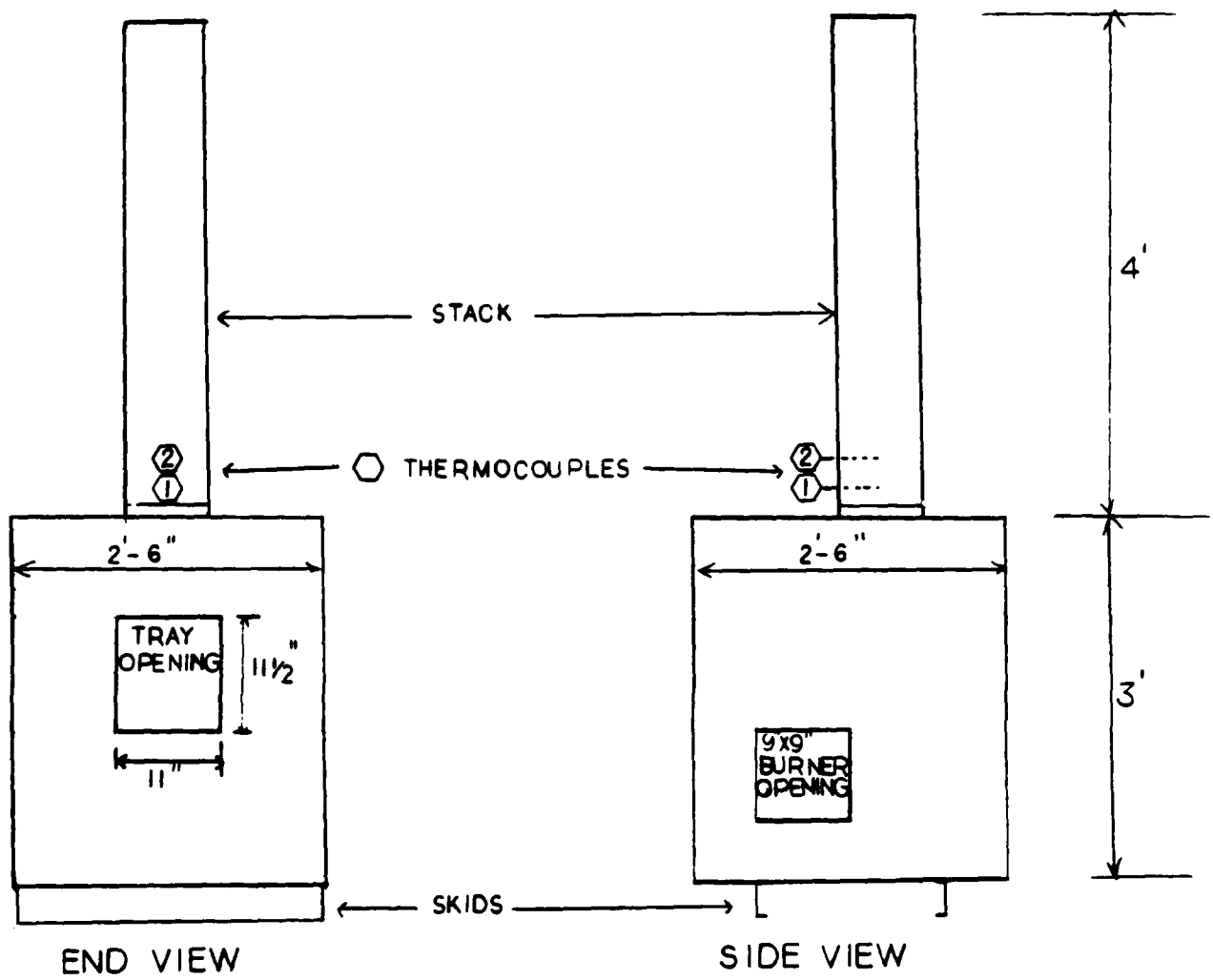
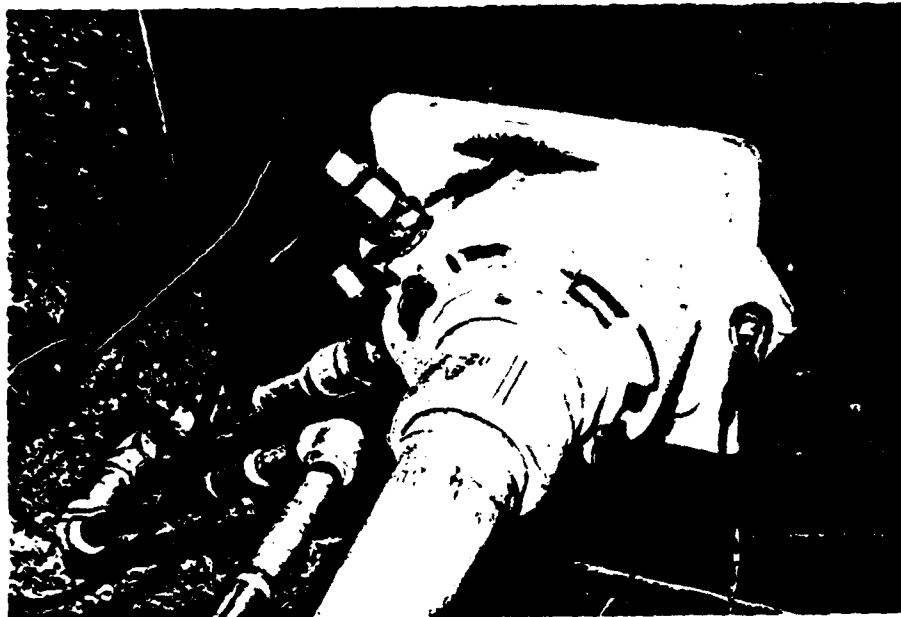


Fig. 4. Furnace.

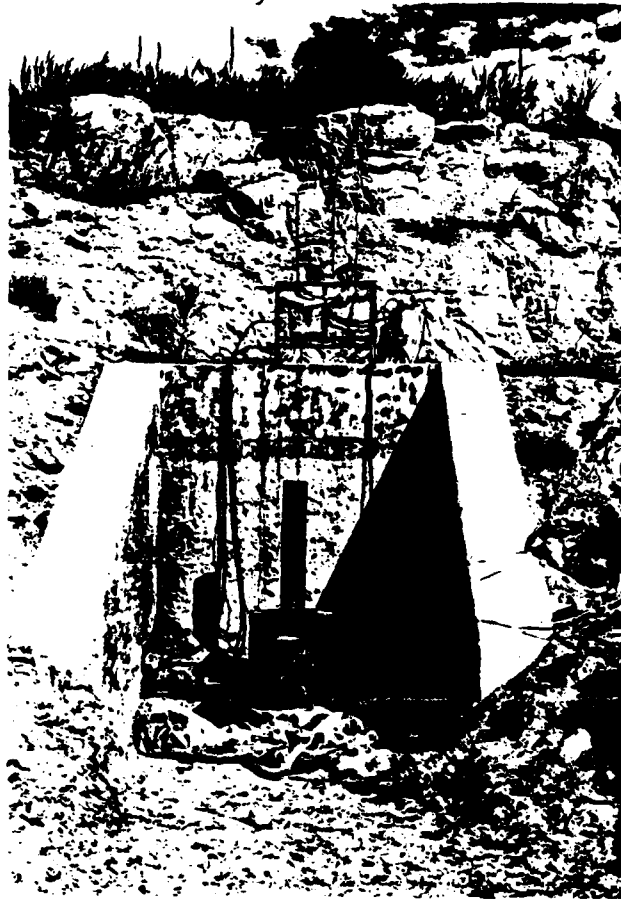


A. View of pilot, ignition plug,
and flame safeguard.

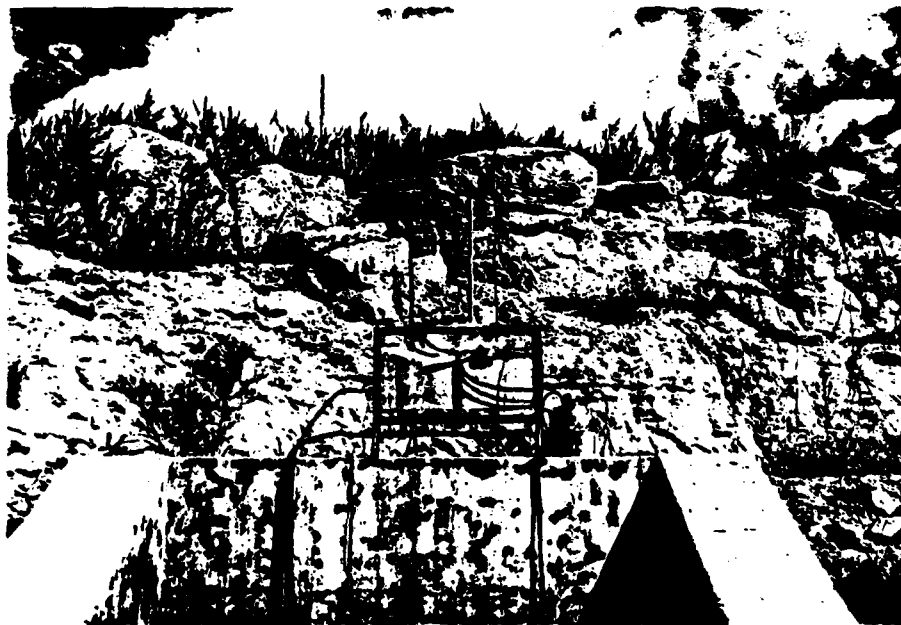


B. View of hose connections,
gauges and main manual
shut-off.

Fig. 5. Propane burner.



A. Firebox set up inside the firing site.



B. Propane cylinder and pipe rack above the firing site.

Fig. 6. Test equipment located at the concrete firing site.

Propane Fuel Supply and Temperature-Control System

Temperature in the firebox was controlled by the flow of propane fuel. Fuel flow was controlled by a pneumatically actuated control valve driven by a 3-30 psi (20.68-207 kPa) signal from a current-to-pneumatic (I/P) converter. The I/P converter received a milliamp signal from the panel-mounted temperature controller located in the control room (Figs. 7A and 7B). Temperature signals were transmitted to the controller from thermocouples in the base of the firebox stack, thus completing the loop.

A propane fuel tank was located near the test unit but out of direct line of sight (Figs. 6A and 6B). All other propane equipment was located on a pipe rack between the test unit and the propane cylinder (Fig. 6B). Safety interlocks for the burner pilot allowed a double block and bleed on the main fuel supply line to open when the pilot flame was detected. The same flame-safeguard system would close the double block and bleed if a flame failure occurred.

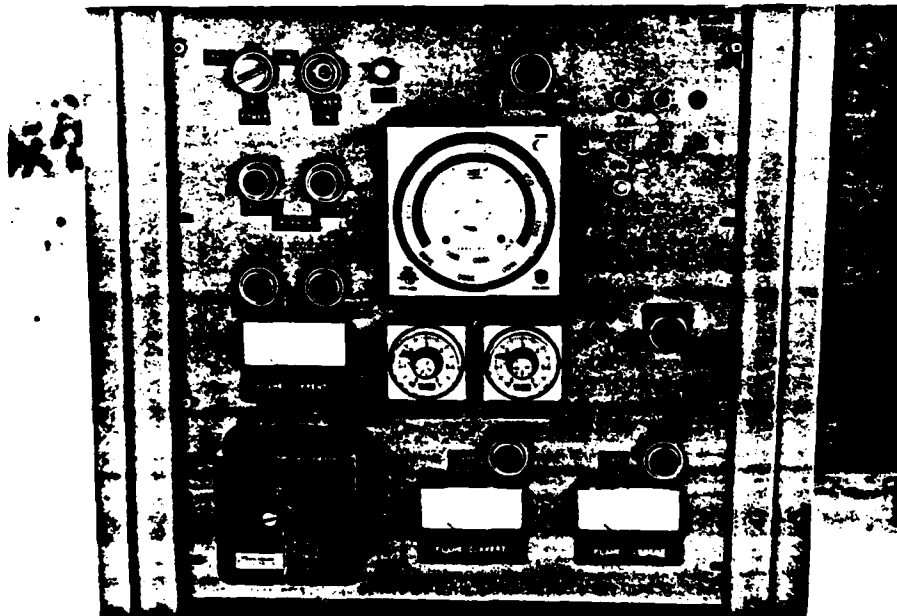
Monitoring System

Temperature monitoring was accomplished by the use of type K thermocouples. Two thermocouples (TC1 and TC2) were installed in the base of the firebox stack, one for temperature control and the other for recording the firebox temperature on the 0-2000°F (-17.78-1093°C) chart recorder (Fig. 4). Tray temperatures were sensed by three thermocouples (TC3, TC4, and TC5) buried about one inch (25.4 mm) below the soil surface in the front, middle, and back of the tray respectively (Fig. 1). Tray temperatures were recorded on a 0-500°C chart recorder. Temperature recording and control units were panel mounted and located in the control room (Figs. 7A and 7B).

Flames in the test tray were sensed by two uv detectors mounted where the line of sight would include only flames produced by burning inside the tray. The first detector was mounted at the back of the tray and pointed down the length of the tray, the second one was installed on the side wall and pointed to see across the tray. Both detectors activated an alarm and a red light on the panel when flames were sensed.



A. Chart temperature recorders,
top and bottom.



B. Burner controls, flame indica-
tion and temperature controller.

Fig. 7. Control panel and instru-
mentation.

Visual monitoring was provided by a fixed-focus, black-and-white video camera mounted at the test unit and positioned to view the tray. A black-and-white video monitor and video recorder were located in the control room.

Tray Temperature and Flame Control System

Inert-gas-purge and water-spray systems were installed for temperature and flame control. The purge-gas cylinder, located on a landing above the test unit and out of the line of sight, also supplied pressure for the propane control valve actuator. All associated gas piping was installed on the common pipe rack with the propane fuel controls and the ignition transformer.

Water spray was provided by a hollow-cone, atomizing spray nozzle mounted in the middle of the back tray wall, one inch (25.4 mm) above the level of the soil. The spray nozzle was rated for 2 gal./h at the 40 psi (276 kPa) pump pressure. A small gear pump with a 5-gal. reservoir provided water pressure. Power for the pump was supplied and controlled from the fire-control room.

Test Procedure

The 9-in. (0.23-m)-deep test tray was half filled [\sim 4.5-in. (114 mm)] with the HE-contaminated soil sample. The burner was ignited remotely, then the firebox temperature was increased rapidly to \sim 1500°F (816°C). The tray was inserted by remote control at \sim 3 in. (76 mm)/min and was fully inserted after 5 minutes. The specified test duration was 30 minutes with the tray inside the firebox exposed to 1500°F. Flame indication by the uv detectors or unusual occurrences were noted either on the temperature chart or in a separate notebook along with the current time and test conditions.

Three variations of the same test were run using soil samples from the same source and the same equipment setup. The first trial was performed with inert gas (nitrogen) purge and the second trial used a 2 gal./h water spray to

determine the effectiveness for controlling HE decomposition and flame in the conveyor. A final run was made to observe the effects with cooling from the bottom water jacket as the only control.

RESULTS

Temperature plots for all three tests are presented in Figs. 8, 9, and 10. The results of each test burn are described briefly below.

Burn No. 1 - October 31, 1985

Flame was detected at 11:07 a.m., when the tray was fully inserted into the firebox. Nitrogen purge was activated when the first flame was detected but was stopped when the flame was immediately suppressed. Flame was detected and snuffed again at 11:12 a.m. Tray temperatures continued to rise until a definite, rapid exotherm began at 11:13 a.m.; the exotherm appeared first on TC 3, then on TC 4. TC 3 went off-scale, above the 500°C recording limit, at 11:20 a.m. with TC 4 closely following at 11:25 a.m. TC 5 did not go off-scale until 11:50 a.m. Nitrogen purge was left on continuously beginning at 11:23 a.m. Flame detection went on and off, probably because smoke obscured the uv detectors. The water-supply hose for the water jacket burst at 11:27 a.m. (Fig. 11). Within 30 minutes, the water-jacket temperature increased above 100°C, indicating a total loss of cooling water. When the main burner and pilot were shut down at 11:38 a.m., the tray could not be removed from the firebox. The temperature on TC 5, the one farthest from the furnace, did not begin to rise until 11:45 a.m., after the burner was off and the firebox had begun to cool down. The tray temperatures continued to increase and surpass the firebox temperatures while the firebox temperatures fell, indicating the HE was still burning or vigorously decomposing even though the flame detectors indicated flames only sporadically. Tray temperatures came back on-scale at 12:30 p.m., beginning with the middle thermocouple (TC 4), followed by the

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 DATE: APR 21, 1964
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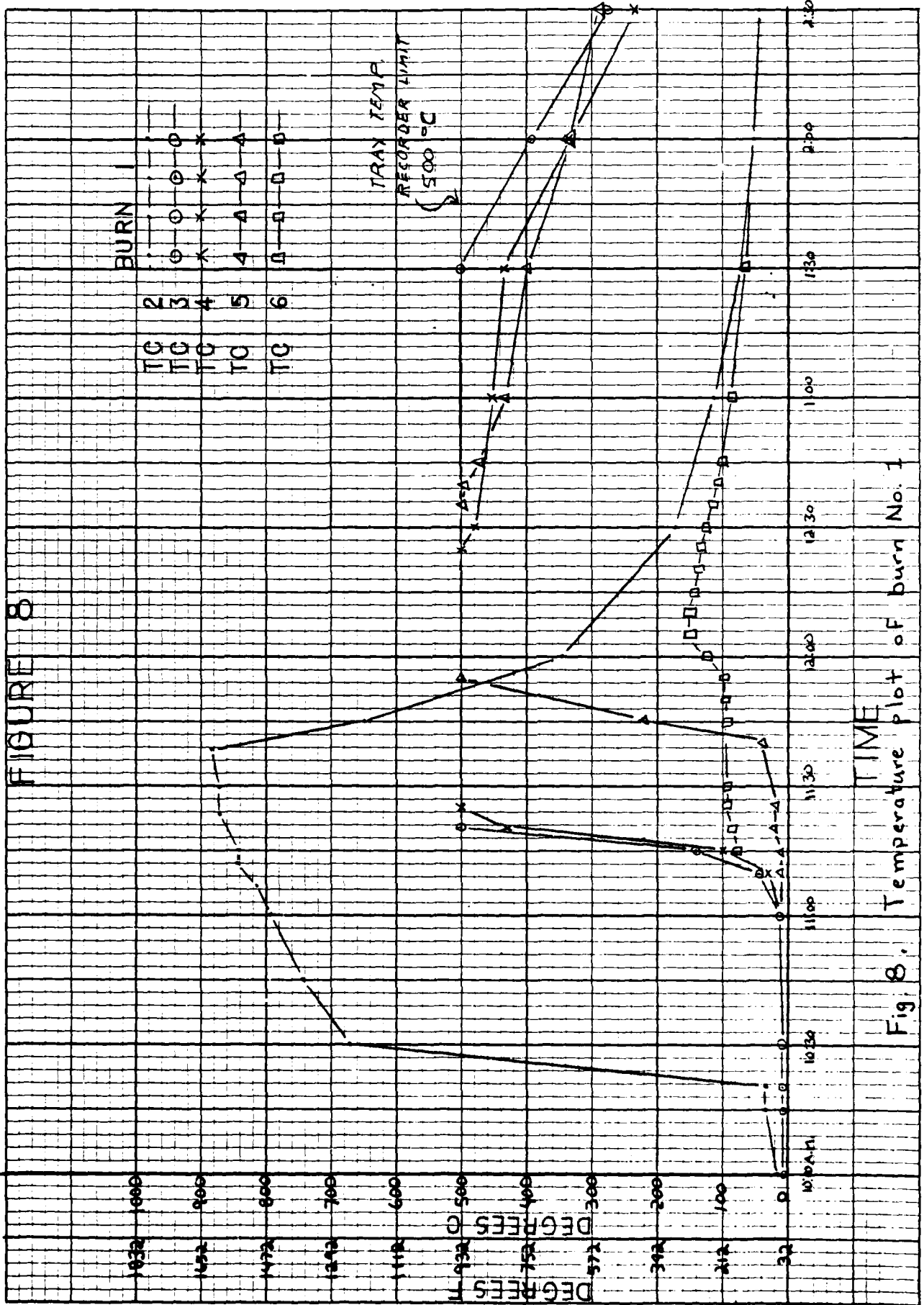


Fig. 8. Temperature plot of burn No. 1

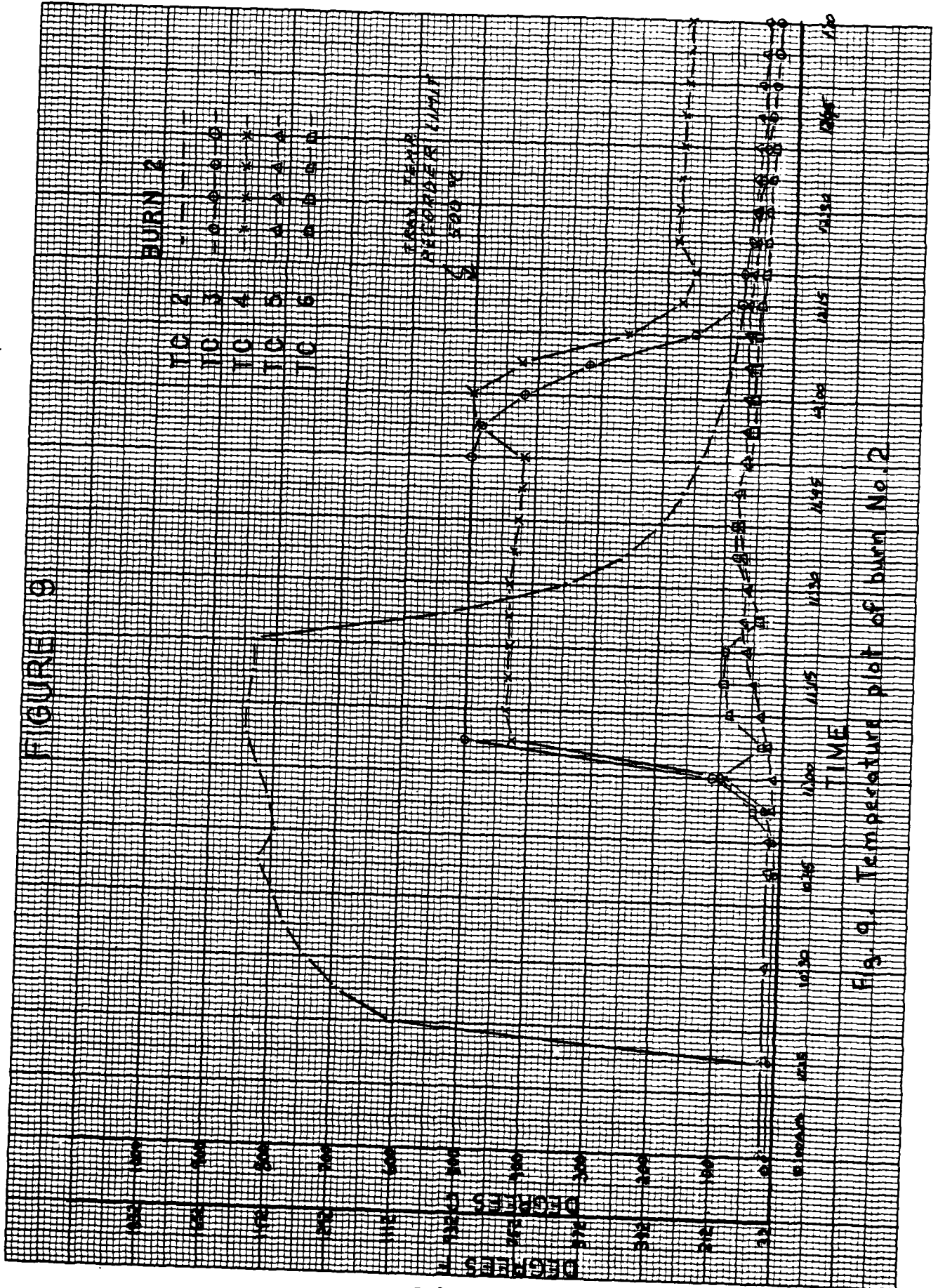


Fig. 9. Temperature plot of burn No. 2


 GENERAL ELECTRIC COMPANY
 Schenectady, New York
 U.S. Patent Office

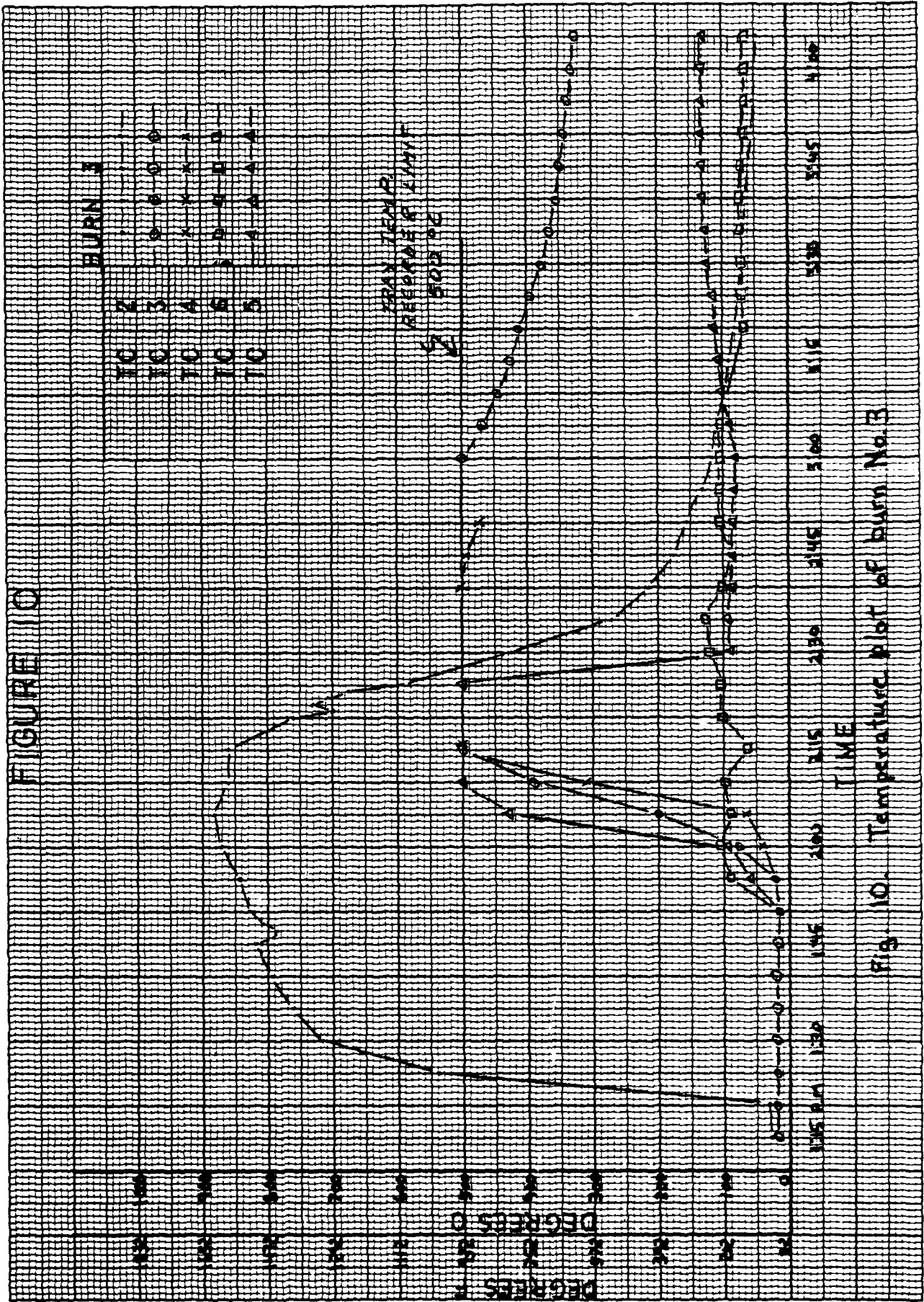


Fig. 10. Temperature plot of Burn No. 3

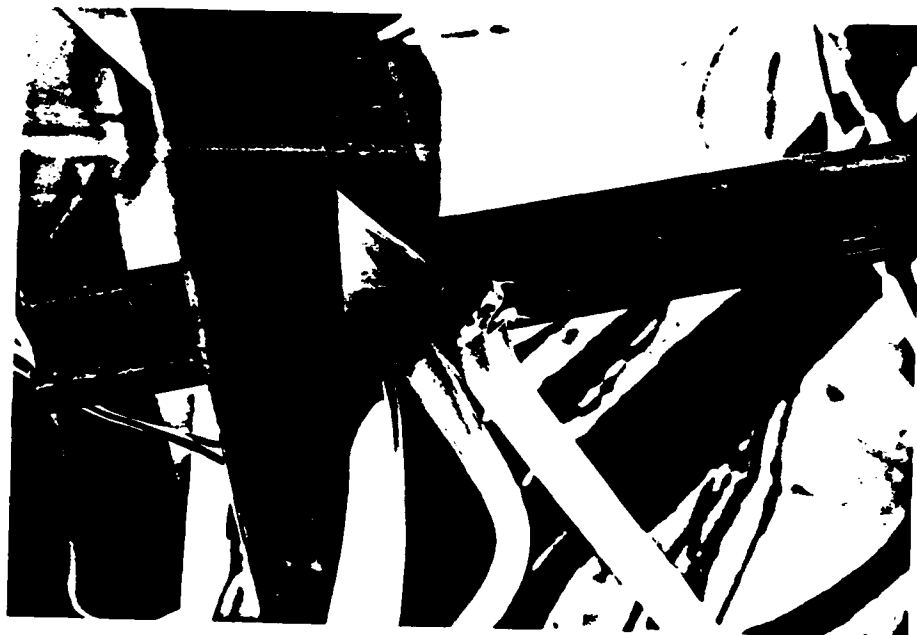


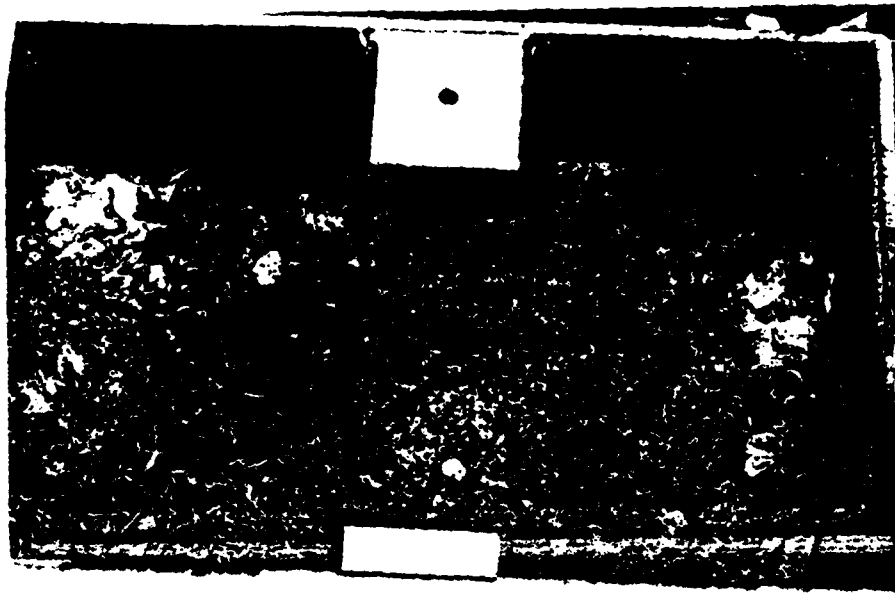
Fig. 11. Ruptured water-jacket
hose after Burn No. 1.

back thermocouple (TC 5) at 12:40 p.m. Finally at 1:15 p.m., the tray withdrawal mechanism responded and the tray was completely removed; this allowed the front TC (3) temperature to come back on-scale at 1:30 p.m. When samples were taken, we saw the entire tray contents had been burned and looked like charcoal. Figures 12A and 12B are photographs showing the soil and tray interior after Burn No. 1.

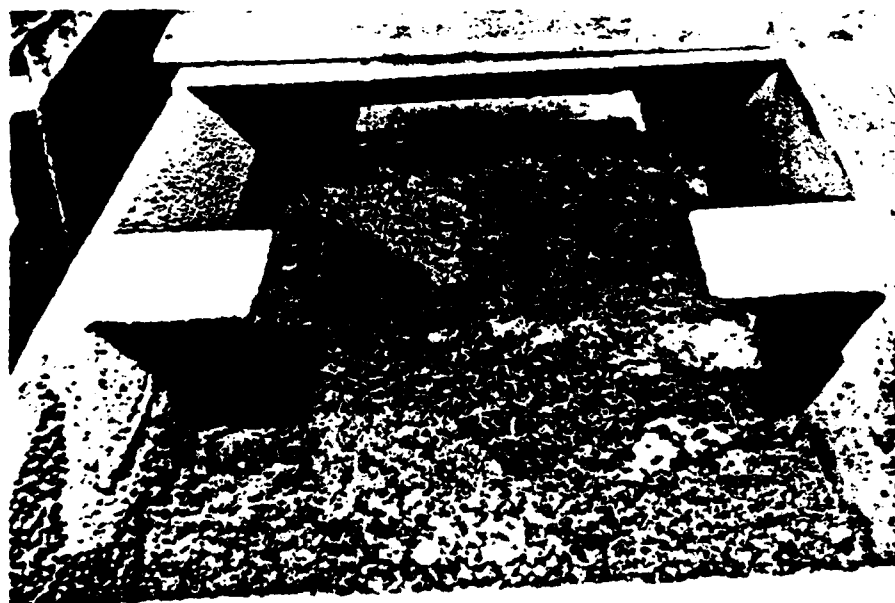
Burn No. 2 - November 5, 1985

The tray was inserted at 10:48 a.m. when firebox temperatures reached 1500°F. Flames were detected in the tray at 11:00 a.m. and were put out with a short-duration water spray. Tray temperatures shot up at 11:02 a.m. beginning with indication on TC 3, then on TC 4. Continuous water spray was used to control the rapid temperature rise. TC 5, farthest from the firebox and closest to the water-spray nozzle, remained below 100°C at all times.

After the 30-min test, the burner was shut down and the tray was removed at 11:21 a.m.. As a precaution, nitrogen purge was used from 11:25 to 11:30 a.m.; then both water spray and nitrogen purge were turned off. Due to high temperatures in the front part of the tray, water spray and nitrogen purge were restarted at 11:34 a.m. and continued until 1:00 p.m., at which time temperatures were again at a safe level. Upon sampling the soil, it was noted that the soil surface in the entire tray was charred black but below the surface the soil appeared unchanged from the original sample material in the rear half of the tray (farthest from the furnace). Below the surface, a definite interface was present between the charred soil in the front of the tray and uncharred soil in the rear. No specific analyses were done on this interface material, but it is assumed that melting TNT at the interface cooled and re-crystallized upon contact with the water. Figures 13A and 13B are photographs of the tray interior and soil.



A. Back part of the tray.

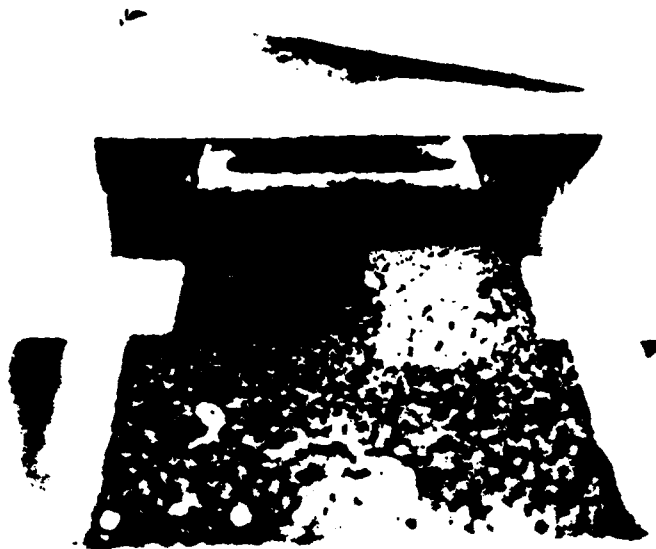


B. View from back to front of the tray.

Fig. 12. Tray interior after Burn No. 1.



A. Back part of the tray showing
water-spray nozzle.



B. View from back to front of the
tray.

Fig. 13. Tray interior after Burn
No. 2.

Burn No. 3 - November 6, 1985

The tray was fully inserted at 1:45 p.m. and the first flame was detected at 1:46 p.m.; flame indication was sporadic during the remainder of the test. There was some indication that the stack temperature increased from 1520 to 1600°F without a corresponding increase in the temperature setpoint at 1:53 p.m.; this is most likely due to rapid burning of HE in the tray.

This 30-min test was completed at 2:16 p.m., when the burner was shut down and the tray removed from the firebox. At 2:19 p.m. flames were noticed extending out of the tray toward the thermocouple and motor control wires, so water spray and nitrogen purge were started to minimize the damage and probability of losing temperature indication. Water spray and gas purge were turned off at 2:28 p.m. and the soil in the tray was allowed to burn itself out. When samples were taken, the entire contents of the tray were charred black as in the first run.

ANALYTICAL RESULTS

Samples were taken after each test burn from six tray locations, the top and bottom at the front, middle, and back of the tray. Sample numbers and locations are marked in Fig. 2. Acetone extractions were performed on samples from each location. Results of each sample analysis are tabulated in Table I.

Results from Burn No. 1:

All the samples collected were charred black and showed almost no weight loss upon acetone extraction.

Results from Burn No. 2:

The forward part of the tray contained essentially no extractable material, while the soil samples from the back part were unchanged from the original samples.

Results from Burn No. 3

Samples from all six tray locations indicated that virtually no acetone extractable material remained after the test.

TABLE I

ACETONE EXTRACTION
RESULTS

<u>Burn No.</u>	<u>Sample No.</u>	<u>Sample Location</u>	<u>Weight Per Cent Acetone Extractable</u>
1	1	TOP-BACK	0.7
	2	BOTTOM-BACK	Nil
	3	TOP-MIDDLE	Nil
	4	BOTTOM-MIDDLE	Nil
	5	TOP-FRONT	Nil
	6	BOTTOM-FRONT	Nil
2	1	TOP-BACK	45.6
	2	BOTTOM-BACK	40.7
	3	TOP-MIDDLE	45.9
	4	BOTTOM-MIDDLE	45.0
	5	TOP-FRONT	Nil
	6	BOTTOM-FRONT	0.2
3	1	TOP-BACK	Nil
	2	BOTTOM-BACK	0.6
	3	TOP-MIDDLE	0.3
	4	BOTTOM-MIDDLE	Nil
	5	TOP-FRONT	0.4
	6	BOTTOM-FRONT	0.4

CONCLUSIONS

1. Exposing this HE-contaminated soil to incinerator temperatures does not pose a threat of rapid deflagration or detonation under the conditions of this test. Incinerating this soil should not cause any such problems in the proposed incineration equipment.

2. Inert-gas purge may be effective in controlling flames on the soil surface, but does not prevent the burning or decomposition reaction from taking place within the soil bed.

3. Water spray is an effective method to stop both flame propagation and decomposition from advancing through the confined screw-conveyor arrangement. If the soil is conveyed while wet, it is doubtful that any burning would be initiated unless most of the water evaporated and the temperature then increased enough to start a reaction.

APPENDIX D
HAZARDS ANALYSIS OF INCINERATOR FEED SYSTEM

0492B

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HAZARDS ANALYSIS
OF
INCINERATOR FEED SYSTEM

JANUARY 1986

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PREPARED FOR

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WESTON WAY
WEST CHESTER, PA

SUBCONTRACTOR'S LETTER AGREEMENT
USATHAMA TASK ORDER 09
(W.O. 2281-01-09)

AO 0803-520-03-001

HERC NO. 86-2

1071t

WARRANTY AND DISCLAIMER

Hercules warrants that it has employed its best efforts in performing the testing reported herein and further that these tests were conducted in accordance with Hercules' test procedures. All other warranties, either expressed or implied, concerning interpretation or utilization of these data, are specifically disclaimed. Within the scope of the work, Hercules warrants that it has exercised its best efforts in performing the hazards analysis hereunder, but specifically disclaims any warranty, expressed or implied, that hazards or accidents will be completely eliminated or that any particular standard or criterion of hazard or accident elimination has been achieved if the findings and recommendations of Hercules Incorporated are adopted.

CAUTION

Conclusions presented in this hazards analysis report are based upon the hardware (or design), materials of construction, operating conditions, process materials and procedures as they existed at the time of the analysis (or as they were presented to Hercules for analysis). If changes in any of these parameters occur in the future, the conclusions of the current hazard analysis may be invalidated.

CAVEAT

Results of the hazards analysis must be considered on the basis that they are based on and apply to the sensitivities of the lagoon sludges tested. The samples tested may not be indicative of all material handled in the Incinerator Feed System and their sensitivities must not be taken as indicative of typical, minimum, or maximum sensitivity of the sludge material.

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SECTION I

SUMMARY

A. OBJECTIVE

The objective of this effort was to perform a Subsystem Hazard Analysis (SSHA) of the Weston Incineration Feed System to assure that the explosives contaminated soil sediment can be safely fed to an incinerating kiln while minimizing the risk of injury to operating personnel and equipment damage. This analysis was supported by sensitivity tests of dried explosives contaminated lagoon sludges. The explosives contaminated sludges were obtained from three Army installations, which are the Louisiana Army Ammunition Plant (LAAP), the Savanna Army Depot Activity (SADA), and the Cornhusker Army Ammunition Plant (CAAP).

B. CONCLUSIONS

The Subsystem Hazard Analysis (SSHA) finds the overall probabilities of initiating a fire within the equipment while handling dried lagoon sludges amounts to the following values per sludge operating hour for the particular materials:

LAAP	-	1.9 E-2*
CAAP	-	7.5 E-3
SADA	-	4.6 E-3

Based upon the probability of handling dried lagoon sludges as opposed to handling wet lagoon sludge, a factor of 1 E-3, the analysis then finds that the overall probabilities of a fire initiating while handling the wet sludges per sludge operating hour amount to the following values:

LAAP	-	1.9 E-5
CAAP	-	7.5 E-6
SADA	-	4.6 E-6

Based further on the expected severity of any incidents the results can be summarized as shown in Table I, Summary Probabilities and Accident Categories for Dried and Wet Lagoon Sludges.

*Probability notation presented in E format; for example, 1.9 E-2 = 1.9×10^{-2} .

TABLE I
SUMMARY
PROBABILITIES AND ACCIDENT CATEGORIES FOR
DRIED AND WET LAGOON SLUDGES

Sludge	Accident Category	Initiation Probability		Criterion
		Dried	Wet	
LAAP	I β	8 E-7	8 E-10	1 E-7
	II α	1.2 E-3	1.2 E-6	1 E-5
	II β	1.2 E-2	1.2 E-5*	1 E-6
	III α	6.1 E-3	6.1 E-6	1 E-3
CAAP	I β	5.2 E-7	5.2 E-10	1 E-7
	II α	1.4 E-7	1.4 E-10	1 E-5
	II β	4.5 E-3	4.5 E-6*	1 E-6
	III α	3 E-3	3 E-6	1 E-3
SADA	I β	2.9 E-7	2.9 E-10	1 E-7
	II α	3.5 E-7	3.5 E-10	1 E-5
	II β	5.8 E-4	5.8 E-7	1 E-6
	III α	4 E-3	4 E-6	1 E-3

*Fails to meet criterion.

Table I shows the wet sludge handling process meets the safety criterion for all the tested sludges in the I β , Catastrophic - Personnel; II α , Critical - Facilities; and III α , Marginal - Facilities Accident Categories. The wet sludge handling process fails to meet the safety criterion for Accident Category II β , Critical - Personnel, when handling LAAP and CAAP wet sludge.

In addition to the Warranty and Disclaimer, Caution, and Caveat statements of page ii, the results of the hazards analysis must be considered on the basis that they are based on and apply to the sensitivities of the lagoon sludges tested. The samples tested may not be indicative of all material handled in the Incinerator Feed System and their sensitivities must not be taken as indicative of typical, minimum, or maximum sensitivity of the sludge material.

The Accident Categories are defined as shown in Table II based upon MPBMA OSM 385-1.(1)

TABLE II
ACCIDENT CATEGORY DEFINITION AND APPLICATION

<u>Category</u>	<u>Definition</u>	<u>Application</u>
I	<u>Catastrophic</u>	
α Facilities	Requires 30 days or more to repair facility.	Not applicable (facility could be replaced in stated time)
β Personnel	Cause death or permanent total disability to one or more persons.	Applicable
II	<u>Critical</u>	
α Facilities	Requires more than three days to repair facility.	Applicable
β Personnel	Cause permanent partial disability to one or more persons.	Applicable
III	<u>Marginal</u>	
α Facilities	Requires less than three days to repair facility.	Applicable
β Personnel	Cause temporary total disability or lost time injury.	Not used
IV	<u>Negligible</u>	
	No damage, no injury.	Not applicable

Accordingly, it is a conclusion of this effort that when handling sludges of the characteristics of LAAP and CAAP sludges, personnel may be exposed to a risk of permanent partial disability that is higher than the accepted criterion. This category is conservatively assigned to the potential for permanent scarring or disfiguring burns.

The scenarios that contribute to the failure to meet the established criterion are shown in Appendix B, Table B-I, Engineering Analysis/Hazards Evaluation Sheet-Hazards Analysis of the Incineration Feed System, as scenarios IA3, IB1, and IV. These items are respectively:

IA3 Hopper being filled and it is bumped or banged with dumper at 0.9 m/s.

IB1 Hopper bridges and operator attempts to clear with a crow bar.

IV Clean-up; sludge spill has air dried and is shoveled up with nonsparking metal tools.

Accordingly several recommendations must be made to meet the criterion. These are considered mandatory recommendations. Other recommendations are offered to improve the risk assessment.

C. RECOMMENDATIONS

Due to the probable variations that can arise in explosive concentrations, soil changes, and moisture content that may increase the sensitivity of the sludges to levels higher than determined by testing the mandatory recommendations are:

1. The Incinerator Feed System (IFS) must be operated remotely (unattended) when handling explosives contaminated soils. The separation between the operating unit and personnel must be based on standard distance tables which take into consideration the hopper's capacity, compaction, explosive concentration, the potential blast overpressure, thermal radiation from a fire ball, and primary fragment dispersion from an explosion.
2. Wooden "bang" boards must be installed on the top flanges of the hopper to prevent accidental metal-to-metal contact of the dumper and hopper.
3. Procedures and rules must be established calling out acceptable tools and techniques for clearing hopper bridging and screw jams. Non-sparking metal tools may not be adequate or proper due to the impact process potentials of the materials.

The nonmandatory recommendations are:

1. Lagoon material should be inspected prior to dumping to assure it is damp, and does not contain rocks or foreign metal materials.
2. Rock, frozen, or dried lumps should not be fed to the IFS.
3. Adequate water should be available for: (a) dampening lagoon material, (b) remote fire fighting, (c) wash out, (d) initiation suppression.
4. Jams in screw conveyors should be washed to remove all possible contamination before attempting repairs

5. Washings of the IFS should be collected for disposal or directed back to the lagoon to prevent contaminating additional soil.
6. All area tools should be accounted for prior to starting or resuming operation of the IFS.
7. Consideration should be given to using wooden, plastic, or fiberglass materials of construction for shovels, rakes, hoes and hopper bridge clearing rods.
8. A combustion products infrared analyzer with samplers located above the hopper and at the final screw outlet may detect early signs of decomposition or initiation and allow for shut down and the addition of quenching water.
9. Personnel in the area should be protected with flame resistant cloth coveralls.
10. Installed air/electric vibrators should be considered as an alternative to the manual clearing of hopper bridging.
11. Additional testing should be considered to determine whether the higher concentrations of explosives such as found in the LAAP sludge will respond with sustained burning and transition to an explosion at energy levels above those found in the process, and which exceed the equivalent energy levels of the sensitivity tests, but which are much lower than the energy levels associated with propagation tests.

SECTION II

INTRODUCTION

A. BACKGROUND AND OBJECTIVES

Roy F. Weston Designers and Consultants is currently developing an incinerator system for explosives contaminated soils and sediments. As part of the development, it is proposed to design, construct, and operate the feed system without a kiln to test the feasibility of the screw conveyor principle in this application. Weston entered into a Subcontractor's Letter Agreement under USATHAMA Task Order 09 (W.O. 2281-01-09) with Hercules Aerospace Division, Allegany Ballistics Laboratory to perform a hazards analysis of the proposed equipment as detailed by Hercules in its Proposals W-5310A and W-5310B, "Hazards Analysis of Incinerator Feed System," based on equipment specifications, process flow diagrams, operating and maintenance procedures, and the results of the sensitivity testing of three lagoon samples.

The samples tested consisted of sludges blended by Los Alamos National Laboratory (LANL) and were originally obtained from lagoons at the Louisiana Army Ammunition Plant (LAAP), Cornhusker Army Ammunition Plant (CAAP), and the Savanna Army Depot Activity (SADA).

Hercules determined the sensitivity of the samples in a vacuum dried condition for response to friction, impact, and electrostatic discharge process potentials.

LANL conducted tests to determine the propagation effects of air dried material (all lagoons), explosives spiked material (SADA and CAAP), sand and water added to lagoon sludge (LAAP).

B. SCOPE AND LIMITATIONS

The Incinerator Feed System (IFS) Hazards Analysis includes the charging of the feed system associated with a bucket/dumper dropping the material into the IFS hopper. The analysis does not include gathering material from a lagoon or transport to the IFS. The analysis extends through the IFS equipment to the last conveyor. Collection of processed lagoon material and transport back to a lagoon site is not included.

The samples tested have been derived from certain sludge lagoons, but the sensitivity results must not be interpreted as being indicative of the typical, maximum, or minimum sensitivity of any or all the material in the lagoons. The sensitivities of the tested material apply only to that material tested.

Lagoon materials were tested in a vacuum dried condition to represent a worst case situation.

Friction material responses were determined at two velocities, three feet (.91 m/s) and ten feet (3.05 m/s) per sec. Where process conditions indicated a lower velocity, the friction response was extrapolated from the test data.

Initiation is defined as any observation or response indicative of or to a combustion process and includes noise, smoke or smoke stain, flame, flash, spark, or an increase above the ambient response of an infrared gas analyzer monitoring for products of combustion, carbon monoxide, carbon dioxide, and oxides of nitrogen.

The analysis does not include an audit for compliance with OSHA type regulations.

C. BASIS OF ANALYSIS

The analysis was based upon the following documentation:

"Test Plan for a Materials Handling Feed System Test of Explosives Contaminated Soils at the Cornhusker Army Ammunition Plant (CAAP), Savanna Army Depot Activity (SADA), and Louisiana Army Ammunition Plant (LAAP)," Roy F. Weston, Inc., West Chester, PA, June 1985.

"Safety Plan for a Materials Handling Feed System Test of Explosives Contaminated Soils at the Savanna Army Depot Activity (SADA)," Roy F. Weston, Inc., West Chester, PA, June 1985.

Thomas & Muller Co., Inc., Camden, N.J., Drawing C-36033, Sheets 1 through 10.

Stretz, L. A., "Propagation and Flame Testing of Explosives-Contaminated Lagoon Soils," Progress Report Through September 1985, Los Alamos National Laboratory, Group M-1.

SECTION III

TECHNICAL APPROACH

The objective of the Hazards Analysis is to quantitatively determine the risk of feeding explosives contaminated soils to an incineration feeding system and to compare the determined risk level to an established and acceptable risk criterion which considers both the operating personnel and the physical facility in order to assure that the explosives contaminated soil/sediment can be safely fed to an incinerating kiln while minimizing the risk of injury to operating personnel and equipment damage.

APPROACH

Hercules utilized its Hazard Evaluation and Risk Control (HERC[®]) methodology to accomplish the hazards analysis of the feed system. This technique combines quantitative test data with analytical engineering to provide the customer the data necessary for evaluation of the risk associated with the facility (or that portion analyzed). The data includes estimates of the severity of fire incidents occurring in the feed system and estimates of the probability of these occurring. This probability can be compared to a predetermined acceptance criterion chosen by the customer. For the purposes of this analysis, the criterion used was based on the requirements of the U. S. Army for modernization and expansion projects, MPBMA OSM 385-1.⁽¹⁾ The results of the analysis are shown in Table B-I, Engineering Analysis/Hazard Evaluation Sheets, Hazards Analysis of Incineration Feed System. The HERC technique consists of several steps as follows:

1. Preliminary Evaluation

The facility to be evaluated is studied for familiarization, with the documentation, determination of credible process potentials, review of materials of construction, potential initiation hazards, and potential effects of an incident.

2. Engineering Analysis

The Engineering Analysis has the objective of determining the process potential that the materials, lagoon sludges in this case, may be exposed to. Based upon the yield strength of the materials of construction and indicated speeds of components, it is possible to determine the frictional forces arising within the equipment, these are the process potentials that the potentially sensitive material may be exposed to. The yield strength of materials of construction represents a rather severe process condition possibly associated with a particular failure mechanism.

Impact process potentials are developed in a similar manner utilizing the drop height, resulting velocity, mass, and an evaluation of the impact area. The impact area may be determined by the physical restraints of an incident or by formula relating mass, yield strength, and the radius of the contracting bodies.

Electrostatic discharge (ESD) process potentials usually depend upon field measurements or previous determinations and their application to the present study. Accordingly, previous work has indicated that an individual can develop a maximum 0.015 J discharge by his actions or movements.

Thermal process potentials were determined by equilibrating the work of the drive motors into a heat value and determining the capacity of the surroundings to conduct the heat away from the sludge material. In this instance, certain engineering estimates were used for the specific heats and thermal conductivities of the sludge material.

The results of the engineering analysis are reported in engineering units comparable to the results of the sensitivity testing.

3. Material Response

The sensitivity testing portion of this study provides the material response information necessary to the completion of the comparison of process potentials and material responses. The Threshold Initiation Level (TIL) of the sensitive material provides a reference mark for comparison with the process potential. The TIL of the sensitivity test indicates the energy level at which zero out of 20 trials show no indication of initiation and is equivalent to a probability of .037.⁽⁸⁾ At least one trial at the next higher test level produced a positive response. The safety margin reported on the evaluation sheets shows a ratio of the highest energy necessary to avoid any sign of initiation to the energy of the process potential arising from an incident or operation. In some instances, the safety margin was less than one. Sensitivity results were reported in the units, as follows:

Impact - Joules/square meter

Friction - Pascals (Newtons/square meter)

ESD - Joules

4. Probability Determination

The end result of determining a fire probability (F_p) is based upon the multiplication of the probability of an event (E_p), the probability of combustible material being present (C_p), and the probability of initiation (I_p). The probability of an event occurring can be based upon the frequency called for in the operating procedure, a human error probability, a mechanical failure rate or may be always present. Human error probability is taken as being 1 E-3 or one out of a thousand. This value is accepted as being typical for a labor intensive, confined type operation.⁽⁶⁾

Material present, (C_p), depends upon the position in the equipment. In most cases, the probability of material being present amounts to one, there are several exceptions to the unity value. These are, the external portions of

the hopper such as the top flanges and sides which may be scraped, or hit by the dumper hopper. In another instance, in attempting to quantify the susceptibility of a dust igniting, the ignition in part calls for a critical concentration being present.

The initiation probability (I_p) is derived from the sensitivity probit plots of the particular sludge. The process potential is read from along the abscissa and the probability is determined from reading the intersection of the process potential of the plot on the ordinate.

The probit plots show the best regression analysis fit to the sensitivity data points. In those friction systems where the velocities were markedly different from the test velocities, a linear extrapolation was made which in effect offsets the Threshold Initiation Level away from the shown plot; in all cases in this study, the extrapolation of the TIL point and the assumption of the nearest slope was to accommodate slower velocities.

The fire probability is a representation of the product of multiplying the event probability (E_p), the material present (C_p), and the initiation probability (I_p) or $(E_p) \times (C_p) \times (I_p) = (F_p)$. Fire probability (F_p), in this instance is a rather severe criterion because it is based upon and includes the probability of initiation which may be indicative of the very first stages of a combustion reaction which evolve only products of combustion, but fails to produce sensible heat, light, or smoke. The fire probabilities can be compared to any acceptable criterion chosen by the customer. Accordingly, if the criterion is established that 1 E-6 is acceptable, then those events that fail to meet the criterion; i.e., have a probability greater than 1 E-6 must be addressed and treated to reduce their probability to an acceptable level. The overall fire probability is determined by taking the summation of all the fire probabilities.

5. Accident Severity

The accident severity is qualitatively appraised under the heading of Hazard Category. The severity of an incident is defined according to the definitions of MIL-STD-882B, "System Safety Program Requirements,"⁽²⁾ and MPBMA OSM 385-1⁽¹⁾ as follows:

TABLE III
HAZARD SEVERITY CLASSIFICATION

<u>Description</u>	<u>Category</u>	<u>Mishap Definition</u>
Catastrophic	I	α Cause system loss, requiring more than 30 days to repair or replace the damage.
		β Cause death or permanent total disability to one or more persons.
Critical	II	α Cause critical system damage requiring more than three days to repair the damage.
		β Causes permanent partial disability to one or more persons.
Marginal	III	α Cause damage which can be repaired in three days or less.
		β Cause temporary total disability or lost time injury not covered by I or II
Negligible	IV	A failure mode not resulting in injury, occupational illness or system damage.

SECTION IV

DESCRIPTION OF THE PROCESS

The process consists of a mechanical design and the equipment to hold and transport explosive contaminated sludge material through a feeder mechanism to prove its feasibility during intermittent operation with explosive contaminated soils (see also Figure 1). This feeder mechanism is a preliminary effort to the proposed subsequent incinerator effort in which a kiln is expected to be fed by the feed system. The eventual complete design is expected to burn the explosive material from the earth on a near continuous basis and allow the residual earth to be returned to the lagoon free of its explosive contamination.

Basically, the process starts with a hopper which is loaded by a self-dumping two cubic yard, steel dumper, operated from a forklift. The main hopper measures six feet long by four feet wide and four feet high. This reinforced hopper contains a breaker bar grid to break large lumps and to protect the personnel. The entire mechanical system is mounted on a bolted, structural steel platform set on concrete foundations.

The bottom of the hopper contains four 12-inch parallel screw conveyors, operating in a counter rotating manner by pairs. The screws are a so-called cone displacement type with solid flights along the cone section and ribbon flights along the remainder of the screws. The hardened flight screws are housed in a trough and driven by chain drive spur gears from a variable speed reducer. The driver is a 15 hp TEFC electric motor to deliver a maximum shaft speed of five rpm.

The output from the hopper's live bottom screws falls through a short chute into the feed section of a twin, counter rotating screw, cross conveyor with 12 inch hardened ribbon flights supported from a five-inch schedule 120-pipe. The screws are turned by a chain from a 7.5 hp variable speed reducer drive. The maximum speed of the screws is 15 rpm. This conveyor and the quad screw are supported by external pillow block bearings with a double bearing on the drive end. The output of this cross conveyor falls through a short chute to a water jacketed incinerator feed conveyor.

The jacketed conveyor is fabricated of Inconel 625 for heat resistance to the kiln's heat. Except for a change in the material of construction, the screw specifications are the same as the cross conveyor. The jackets are baffled to direct the water from the feed end to the outlet end. Water returns to the system through the inside of the screws and a rotary coupling. A chain drive from a 15 hp variable speed reducer turns the shafts at a maximum speed of 15 rpm. This final water jacketed conveyor utilizes double pillow block bearings on the drive end and high temperature hanger bearings on the discharge end. During the preliminary tests without a kiln, water will not circulate through this conveyor.

No drawings were made available of the auxiliaries, but it is reported that certain control and monitoring instrumentation are available. These include:

Alarms - Live bottom hopper	Low motor amps for hopper empty or bridging.
	High motor amps for hopper overloaded or partial jamming of the screws.
	High-high motor amps for jam in live bottom screws. Screws will automatically reverse a partial revolution and attempt to restart.
Alarms - Cross conveyor	High motor amps for partial jamming of conveyor.
	High-high motor amps for jam in cross conveyor. Screws will automatically reverse partial revolution and attempt to restart.
	Live bottom hopper will shut down.
Alarms - Incinerator feed conveyor	High motor amps for partial jamming of conveyor.
	High-high amps for jam of conveyor.
	Live bottom and cross conveyors will shut down. Conveyor will reverse itself a partial revolution and attempt to restart.
Alarm	Low oil pump pressure for bearing purge system due to low oil level in reservoir, pump failure, screw shaft bearing failure, leak in oil purge system.
Alarm	Low-low oil pump pressure for bearing purge system due to the same causes will shut down system.

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INSTALLATION RESTORATION GENERAL ENVIRONMENTAL
TECHNOLOGY DEVELOPMENT FILE (U) WESTON (ROY F) INC WEST
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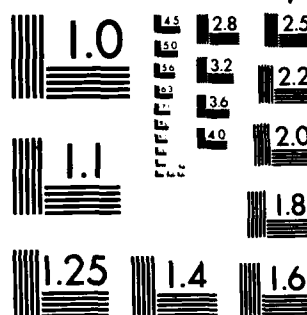
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MICROCOPY RESOLUTION TEST CHART
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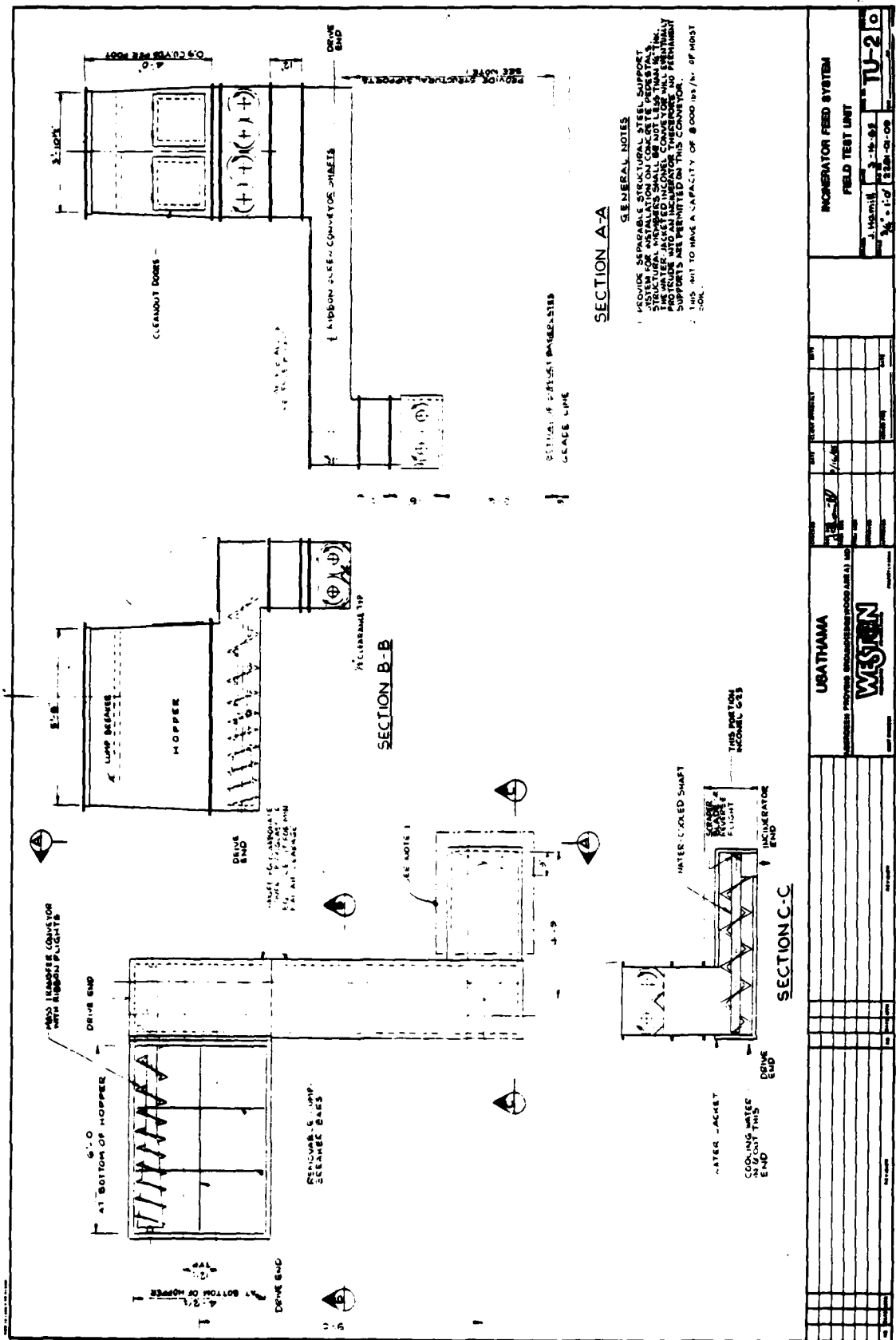


Figure 1

SECTION V

DISCUSSION

A. THE HAZARDS ANALYSIS

The results of the hazards analysis are detailed in Appendix B as Table B-I. The summation of the results shows that initiation of the explosives content of the dried sludge is estimated to occur with the following overall probabilities:

<u>Sludge</u>	<u>Probability of Initiation</u>
LAAP	1.9 E-2
CAAP	7.5 E-3
SADA	4.6 E-3

The sensitivity testing showed that when the most sensitive LAAP sludge was moistened from the 0.28% to the 16.75% moisture level, the impact sensitivity decreases from a relatively sensitive 6.9 cm Threshold Initiation Level (TIL), 7.99 KJ/m^2 , to the full range of the machine or at least a TIL of 120 cm, 1.39 E2 KJ/m^2 . This represents an improvement in the probability of initiation from the 3.7 E-2 at the TIL level of the dry material to a probability of initiation of the wet material of 3 E-8 at the corresponding energy level. The addition of sufficient water to suppress initiation is a critical control to this process.

If the probability of failing to handle the sludge in a moist condition can be assigned the same probability as failing to follow a procedure, there is a basis to assign the probability of 1 E-3 to this human error.^(6,7) Then, if this 1 E-3 probability is assigned to the overall results of the hazards analysis the probability values for initiation of the wet sludge decreases from the previous dried sludge values accordingly:

<u>Sludge</u>	<u>Probability of Initiation</u>
LAAP	1.9 E-5
CAAP	7.5 E-6
SADA	4.6 E-6

When the scenarios of the Engineering Analysis/Hazard Evaluation Sheet were assigned hazard categories to correspond to the definitions of MPBMA OSM 385-1⁽¹⁾ for either personnel death/injuries or facility damages, certain suppositions were made to correlate the data to the criterion documentation. These suppositions are as follows:

1. Normal operation of the feeder system would be carried out remotely (unattended), except for the dumper operator who would be below the hopper intermittently six times an hour.

2. The hazard analysis is based on the probability of an event per sludge operating hour and personnel injuries are based on one person being present during potential personnel injury scenarios, such as clearing hopper bridging.
3. Given that equipment specifications and fabrication drawings are ready and available, the facility could be completely replaced within thirty days with an expedited purchasing and construction effort. This supposition thereby eliminates the $I\alpha$ category for system repair/replacement requiring over 30 days.
4. The $II\beta$ Accident Category is used for personnel injuries other than death or permanent total disability on the basis that such injuries will be fire related resulting in disfiguring or immobilizing scars and could be classified as a permanent partial disability injury by the local jurisdiction compensation board.
5. Normal operating event severities are based on no personnel present and are therefore categorized into either the $II\alpha$ or $III\alpha$ accident category, depending upon an estimate of the time to repair or replace the facility.

As shown in Table I, the $I\beta$, Catastrophic - Personnel, accident category ranged from 2.9 E-10 to 8.0 E-10 with the wet sludges as compared to a criterion of 1 E-7 . The $II\alpha$, Critical - Facility, accident category ranged from 1.4 E-10 to 1.2 E-6 against a criterion of 1 E-5 . The $II\beta$, Critical - Personnel, accident category showed results from 5.8 E-7 to 1.2 E-5 with a criterion of 1 E-6 . The $III\alpha$, Marginal - Facility, accident category showed results between 3 E-6 and 6.1 E-6 with a criterion of 1 E-3 . In all instances, the LAAP sludge had a higher probability of initiation than either the CAAP or SADA sludges. The LAAP and CAAP sludges failed to meet the criterion for the hazard Category $II\beta$, Critical - Personnel, based on the probability and estimated incident severity which would result in permanent partial disability based on burns and disfiguring or partially immobilizing scarring.

The scenarios in Table B-I which contribute to exceeding the established criterion are the following:

- | | |
|--------------|---------------------------------------------------------------------------------------------------------|
| Scenario IA3 | Hopper is being filled and it is banged by the dumper at 0.9 m/s . |
| Scenario IB1 | The hopper bridges and the operator attempts to clear the bridge with a crow bar or similar metal tool. |
| Scenario IV | A spill occurs and is allowed to dry out and then is scooped with a metal scoop or shovel. |

TABLE I
SUMMARY
PROBABILITIES AND ACCIDENT CATEGORIES FOR
DRIED AND WET LAGOON SLUDGES

<u>Sludge</u>	<u>Accident Category</u>	<u>Initiation Probability</u>		<u>Criterion</u>
		<u>Dried</u>	<u>Wet</u>	
LAAP	I β	8 E-7	8 E-10	1 E-7
	II α	1.2 E-3	1.2 E-6	1 E-5
	II β	1.2 E-2	1.2 E-5*	1 E-6
	III α	6.1 E-3	6.1 E-6	1 E-3
CAAP	I β	5.2 E-7	5.2 E-10	1 E-7
	II α	1.4 E-7	1.4 E-10	1 E-5
	II β	4.5 E-3	4.5 E-6*	1 E-6
	III α	3 E-3	3 E-6	1 E-3
SADA	I β	2.9 E-7	2.9 E-10	1 E-7
	II α	3.5 E-7	3.5 E-10	1 E-5
	II β	5.8 E-4	5.8 E-7	1 E-6
	III α	4 E-3	4 E-6	1 E-3

*Fails to meet criterion.

These three impact scenarios essentially account (more than 99%) for the failure to meet the criterion and require either procedural or facility changes to meet the requirement. Since the probability of the accident category fails to meet the criterion, the changes or recommendations are mandatory to reach compliance with the risk standard.

- The Incinerator Feed System (IFS) must be operated remotely (unattended) when handling explosives contaminated soils.
- Wooden "bang" boards must be installed on the top flanges of the hopper to prevent accidental metal-to-metal contact of the dumper and hopper.
- Procedures and rules must be established calling out acceptable tools and techniques for clearing hopper bridging and screw jams. Non-sparking metal tools may not be adequate or proper due to the impact process potentials of the materials of construction. Wood, fiberglass, and plastic tools have a much lower impact process potential when used under the same conditions and should be considered.

The use of proper tools and the installation of wooden "bang" boards on the hopper flanges will reduce the risk of initiation to an acceptable level to meet the accident Category II β criterion.

Although the process potential of friction is the most likely mechanical process to occur in the screw feeders, impact events appear to develop a stronger sensitivity reaction and should be minimized. The following recommendations are offered to minimize impact events:

- Lagoon material should be inspected prior to dumping to assure it is damp, and does not contain rocks, metal, or other foreign materials.
- Rock and frozen, or dried lumps should not be fed to the IFS.
- Consideration should be given to using wooden, plastic, or fiberglass materials of construction for shovels, rakes, hoes, and hopper bridge clearing rods.
- Installed air/electric vibrators should be considered as an alternative to manual clearing of hopper bridging.

Other nonmandatory recommendations which appear warranted are:

- Adequate water should be available for (a) dampening lagoon material, (b) remote fire fighting, (c) wash out, and (d) initiation suppression.
- Install a remotely-operated fire monitor.

- Jams in screw conveyors should be washed to remove all possible contamination before attempting to make repairs.
- Washings from IFS should be collected for disposal or directed back to the lagoon to prevent contaminating additional soil.
- All area tools should be accounted for prior to starting or resuming operation of the IFS.

In almost all the sensitivity testing, exceptions being the LAAP impact tests and LAAP electrostatic discharge tests, the only indication of nascent combustion of the explosives was the detection of the products of combustion, carbon monoxide, carbon dioxide, and nitrous oxide. No sensory signs of combustion were otherwise apparent. There may be some benefit to installing a similar type of infrared detector with sampler points located above the hopper and at the discharge screw to monitor for the presence of these products of combustion which would allow for shutdown, increased dampening of the soils, and clearing the area as a precaution.

The highest impact process potential, indicated by the engineering analysis section of the hazard analysis showed an energy level of 4.1 E6 J/m^2 in Scenario IA5. This energy level is greater than the Threshold Initiation Level (TIL) of all the tested sludges. In the case of the LAAP sludge, sensory evidence of a combustion process was present as noise, smoke, and smoke stain. Higher material response data can be extrapolated from the LANL propagation tests which indicate that when the LAAP material is subjected to an energy level equivalent to approximately $1.2 \times 10^{10} \text{ J/m}^2$ the LAAP explosives content did in fact propagate. This difference in energy levels of approximately 3000 times leaves an unanswered question as to the LAAP material's next response after an almost instantaneous initiation, i.e., possible sustained burning, and possible transition to an explosion, within the actual screw conveyor mechanism.

A partial answer to the question may be resolved should LANL perform the simulated screw conveyor propagation test, particularly if the test can also simulate the compaction and voids that will develop along the screw flights.

The potential during the trial operation of the Incinerator Feed System for variations in explosive concentrations within the sludges, soil composition, and moisture content can act to negate the results of the sensitivity testing which was performed on specially prepared samples. It must be borne in mind and practice that the sensitivity results and the hazards analysis based on those results apply only to the samples tested and cannot be applied generally to any sludge material removed from a particular lagoon.

B. SENSITIVITY TESTING

A brief discussion of the sensitivity testing methods and the results of the sensitivity tests are included in Appendix A.

1. Impact Sensitivity Discussion

As seen from Tables AI, AII, and AIII, and the accompanying figures, the impact response for dried sludge ranged from no reaction with the CAAP sludge at the full height of the apparatus, 120 cm, to a noise, smoke, and LIRA[®] response until the drop height was reduced to 6.9 cm for the LAAP sludge at which time no response was detected. A 6.9 cm, (7.99 KJ/m²), impact height is relatively sensitive, being more sensitive than either TNT or RDX alone⁽³⁾ where previous results have shown 22 to 67 KJ/m² and 27 KJ/m², respectively, for these explosive ingredients in the dry, solid, and fine condition. The SADA sludge was slightly more sensitive than CAAP sludge showing no reaction at 100 cm drop height.

When approximately 16.5% water was added to the dried LAAP sludge, the impact sensitivity was decreased markedly from the 6.9 cm height to the full range of the apparatus or 120 cm.

<u>Sludge</u>	<u>Volatiles (%)</u>	<u>Drop Height (cm)</u>	<u>Energy/Area (kJ/m²)</u>
SADA	.23	100	1.2 E2
CAAP	.15	Greater than 120	Greater than 1.4 E2
LAAP	.28	6.9	8.0
LAAP	16.75	Greater than 120	Greater than 1.4 E2

2. Friction Sensitivity Discussion

All friction responses were detected by the LIRA analyzer with no other sensory perception apparent. The most friction sensitive sludge was the CAAP sludge showing initiation to a force until the 3.75 E2 MPa pressure level was reached at 0.91 m/s. Interestingly, it was found that this same sludge was the least friction sensitive sludge at 3.05 m/s.

Relatively, the sludges showed the following Threshold Initiation Levels (TIL):

<u>Sludge</u>	<u>Lower Velocity 0.91 m/s</u>	<u>Higher Velocity 3.05 m/s</u>
SADA	4.36 E2 MPa	2.27 E2 MPa
CAAP	3.75 E2 MPa	3.06 E2 MPa
LAAP	5.21 E2 MPa	2.34 E2 MPa

The highest friction response was indicated by the LIRA analyzer on LAAP sludge and amounted to 32 ppm products of decomposition, CO₂, CO, or N₂O.

Dry, solid TNT alone has shown no friction response at the 3.6 E2 MPa level while dry, solid RDX has shown no friction response at 2.4 E2 MPa when previously tested at the 3.0 m/s velocity.⁽³⁾ Accordingly, the dry lagoon sludges are as sensitive or more sensitive than the neat ingredients, possibly due to the effect of a hard granular additive, sand.

3. Electrostatic Discharge Sensitivity (ESD) Discussion

The dry sludge samples showed the following ESD TIL responses:

	<u>Joules</u>
SADA	0.075
CAAP	0.500
LAAP	0.024

Not only was the LAAP sludge the most sensitive, it also showed a more energetic response consisting of flame, smoke, and a full-scale deflection on the infrared analyzer. The ESD responses indicate the dry SADA and LAAP sludge samples are as sensitive as neat RDX and TNT, respectively, 0.075 and 0.024 Joule.(3)

4. Sludge Analyses and Propagation Testing

The Los Alamos National Laboratory Progress Report (see Basis of Analysis) shows the following explosive identification and concentrations of the lagoon's sludges when dried.

TABLE IV

LAGOON SAMPLE DESCRIPTION AND ANALYSES

<u>Source</u> <u>Lagoon</u>	<u>Description</u>	<u>Moisture,</u> <u>Wt., %</u>	<u>Explosives Con-</u> <u>tent by Weight, %</u>	<u>TNT/Nitra-</u> <u>mine* Ratio</u>
SADA	Sandy, no visible ex- plosives	4.55	4.6	All TNT
CAAP	Gummy, no visible ex- plosives	6.82	5.4	2.4
LAAP	Sandy clay, chunks of TNT	5.92	44.2	3.3

*RDX and HMX

A summary of the Los Alamos tests reported that all sludge samples would not propagate with an explosives content less than 25% when diluted with sand. On the other hand, LAAP samples wetted with water up to the 20% by weight level still propagated when exposed to a Composition B booster charge greater than 0.9 pound for the four-inch propagation test and more than 2.59 pounds for the six-inch propagation test.

Generally, it is considered that an explosion arises from the following process, (1) initiation, (2) sustained burning, and (3) transition to an explosion. In the case of high explosives, the time frame between the process phases may be very short while in less condensed explosives, the time frame may be much longer; i.e., the ammonium nitrate explosion at Texas City, Texas. The present sensitivity tests treat only the question of initiation of dried sludge material which in most cases was evidenced by the detection of products of combustion. It is not definitely known whether the LAAP samples reached the sustained burning stage during the impact and ESD testing but there can be no question about developing initiation.

Certain tests are available which expose the test sample to graduated and calibrated relatively high energy thermal sources between the tests for initiation and the high explosive boosted propagation test, as conducted by LANL. These tests consist of exposing the sample to impact energy equivalent sources at the 1.296 E6 J/m^2 and 8.02 E6 J/m^2 to better determine whether sustained burning has in fact been accomplished.⁽⁴⁾ The performance of these tests was not within the scope of the present work.

5. Thermal Sensitivity Discussion

The hazards analysis included several scenarios to evaluate the heat generation due to frictional forces. The heat generation was based on equilibrating the frictional force, pounds force, and the applicable lever arm to foot pounds and subsequently converting this value to Btu/hr. An estimate was made of the soil's and surroundings' thermal conductivities and specific heats relative to the situations' ability to conduct heat away from the source of generation.

This value resulted in a temperature rise per hour which was then compared to the heat tests performed on RDX and TNT for 100 hours at 100°C .⁽⁹⁾ The reference shows that neither TNT or RDX explodes in 100 hours at 100°C . It does indicate that RDX with a melting point of 204°C will lose 0.04% weight in the first 48 hours and no loss in the second 48 hours. TNT under the same conditions may melt at 81°C and will lose 0.2% during both the first and second 48 hour periods. There is no indication that these materials reach an active burning condition during this time temperature exposure. The same reference⁽⁹⁾ shows RDX and TNT undergoing decomposition without an explosion at 260°C and 475°C respectively.

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4. "HERC Risk Analysis Manual," Edition I, HERC No. 75-79, Hercules Incorporated, Allegany Ballistics Laboratory, Cumberland, MD, October 1975, p. III-90. (Proprietary)
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APPENDIX A

SENSITIVITY TESTING OF SLUDGES

A-1

D-29

APPENDIX A

A. SENSITIVITY RESULTS

TABLE A-I

SENSITIVITY RESULTS SAVANNA ARMY DEPOT ACTIVITY (SADA) LAGOON SLUDGE

Impact Test - (See Figure A-1)

Dry material, 0.23% volatiles
Components: Tool steel/tool steel.

<u>Height, cm</u>	<u>Energy, KJ/m²*</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
100	1.16 E2	0	20	No reaction
120	1.39 E2	1	18	LIRA**

Friction Test - A (See Figure A-2 and A-3)

Dry material, 0.23% volatiles
Components: Tool steel/tool steel
Velocity 0.91 m/s

<u>Pounds-Force</u>	<u>Pressure, MPa***</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
305	4.37 E2	0	20	No reaction
400	5.21 E2	1	10	LIRA
560	6.46 E2	5	10	LIRA
680	7.32 E2	7	10	LIRA
840	8.38 E2	9	10	LIRA

Friction Test - B (See Figure A-2 and A-3)

Dry material, 0.23% volatiles
Components: Tool steel/tool steel
Velocity 3.05 m/s

* Kilo Joules per square meter.

** LIRA[®] - the registered trademark for Mine Safety Appliance Company's brand of infrared analyzer. This instrument is calibrated for an infrared absorption response to low values of carbon monoxides, carbon dioxide, and nitrous oxides, products of combustion.

***Mega Pascals.

TABLE A-I (CONT'D.)

Friction Test - B (Cont'd.)

<u>Pounds-Force</u>	<u>Pressure, MPa*</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
110	2.27 E2	0	20	No reaction
220	3.55 E2	1	10	LIRA
305	4.37 E2	2	10	LIRA
400	5.21 E2	6	10	LIRA
580	6.62 E2	7	10	LIRA
830	8.32 E2	9	10	LIRA

ESD Test (See Figure A-4)

Dry material, 0.23% volatiles

<u>Energy, Joules</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
0.075	0	20	No reaction
0.500	10	10	LIRA

*Mega Pascals.

SADA SLUDGE
VAC DRIED POWDER
THRU 20 MESH

IMPACT

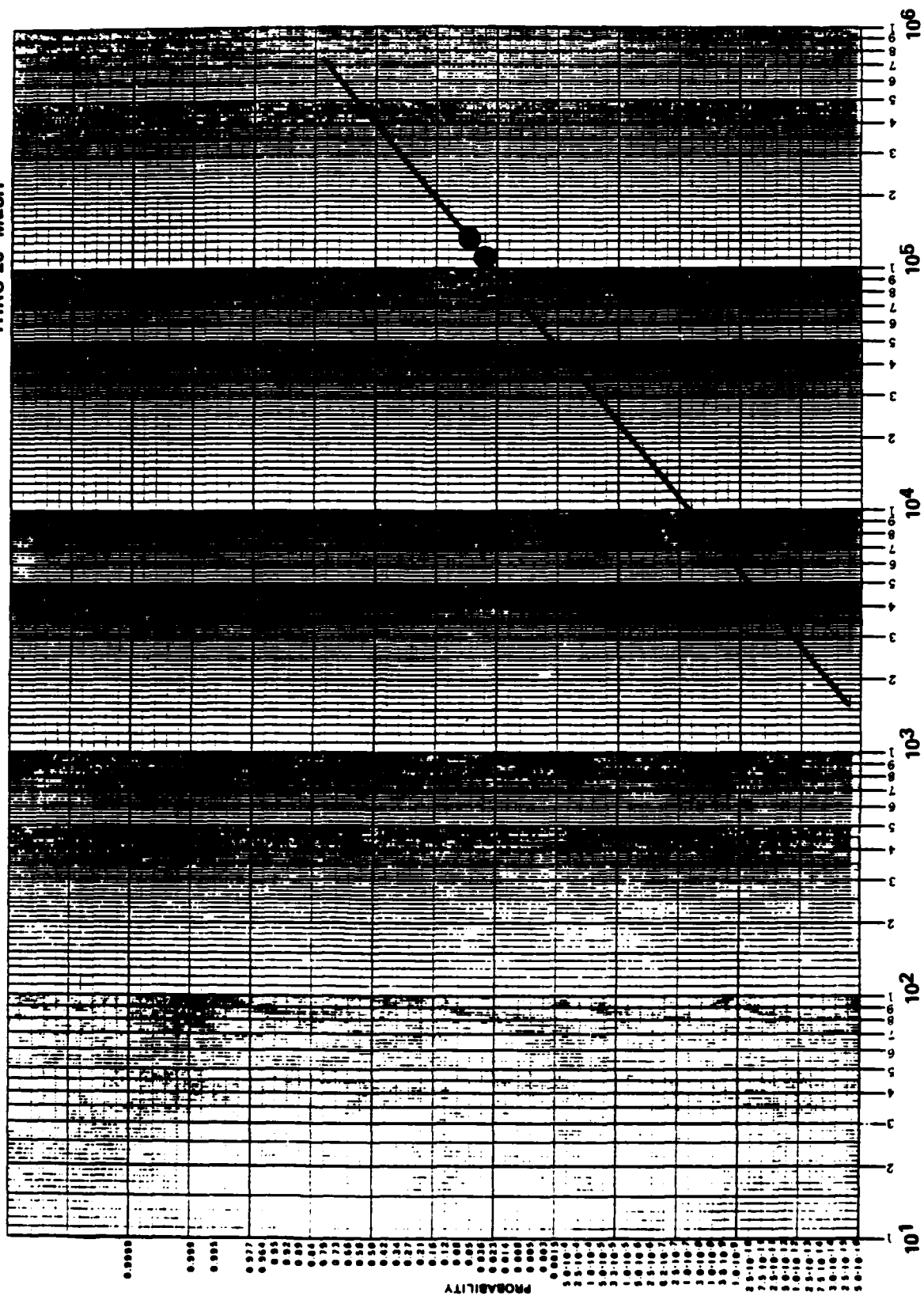


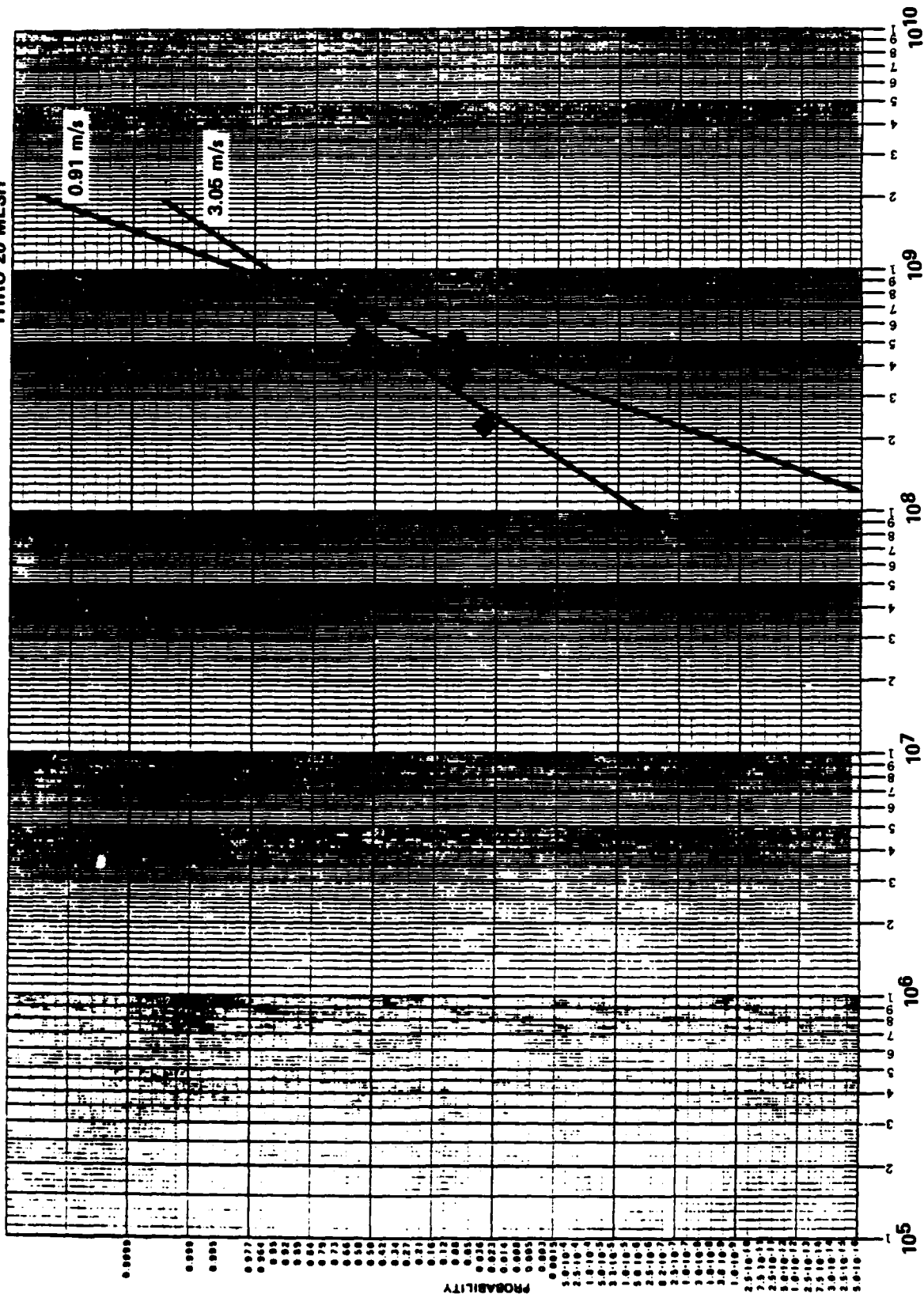
Figure A-1

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SADA SLUDGE
VAC DRIED POWDER
THRU 20 MESH

FRICTION



A-5

D-33

Figure A-2

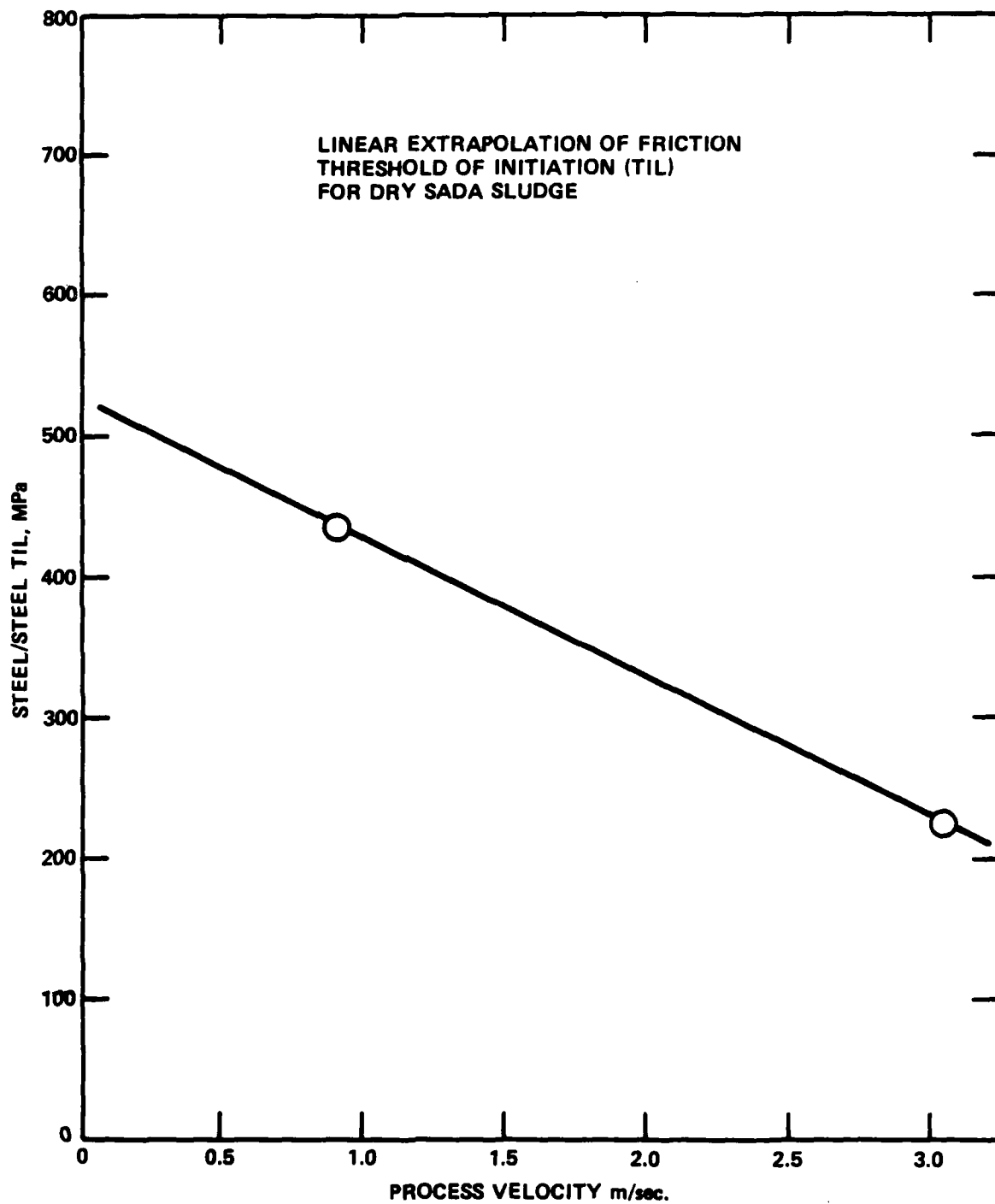


Figure A-3

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SADA SLUDGE
VAC DRIED POWDER
THRU 20 MESH

ESD

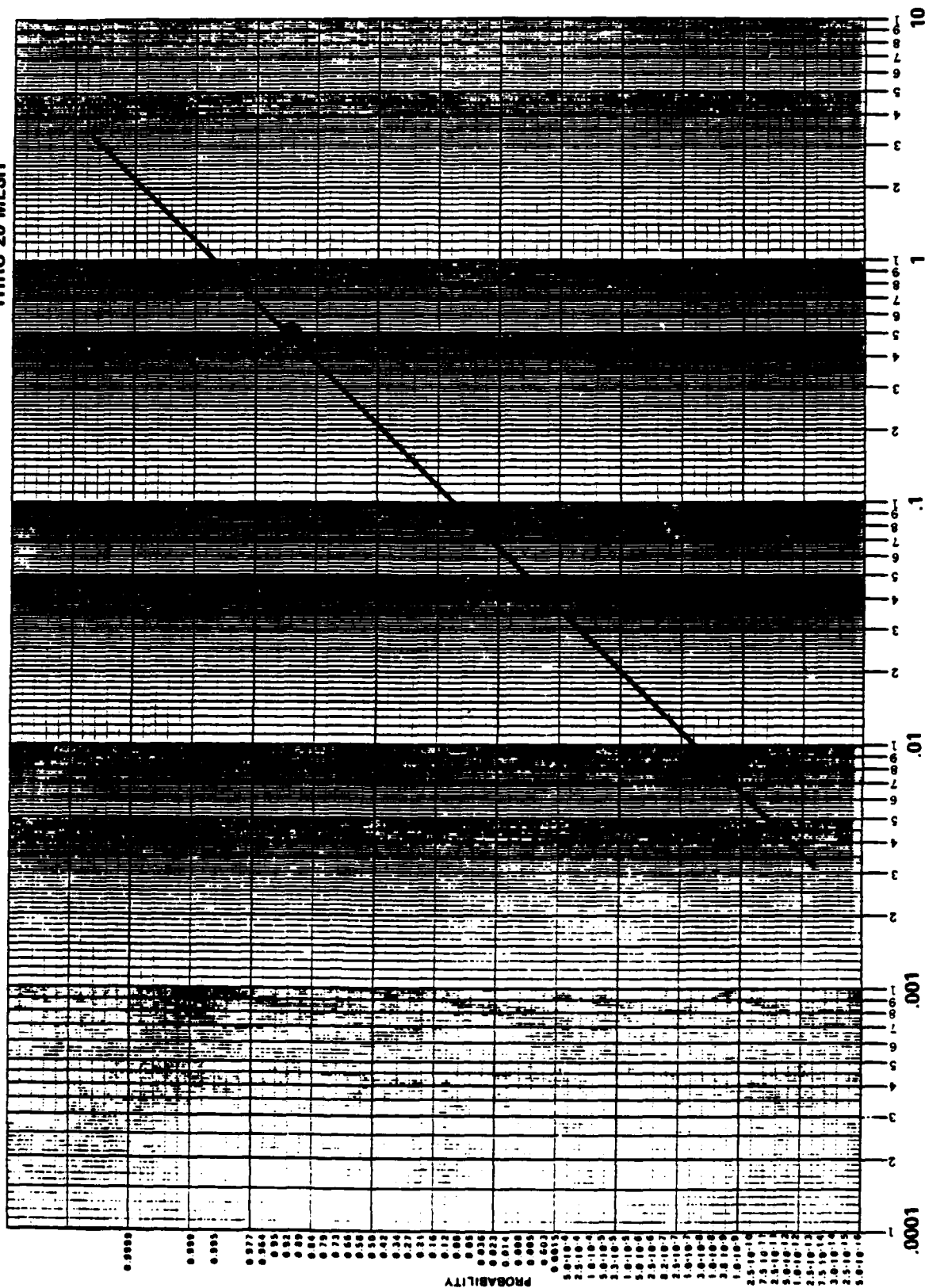


Figure A-4

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TABLE A-II
SENSITIVITY RESULTS
CORNHUSKER ARMY AMMUNITION PLANT (CAAP) LAGOON SLUDGE

Impact Test - (See Figure A-5)

Dry material, 0.15% volatiles
Components: Tool steel/tool steel.

<u>Height, cm</u>	<u>Energy, KJ/m²*</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
120	1.39 E2	0	20	No reaction

Friction Test - A (See Figure A-6 and A-7)

Dry material, 0.15% volatiles
Components: Tool steel/tool steel
Velocity 0.91 m/s

<u>Pounds-Force</u>	<u>Pressure, MPa**</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
240	3.75 E2	0	20	No reaction
330	4.60 E2	4	10	LIRA
375	4.99 E2	5	10	LIRA
405	5.25 E2	9	10	LIRA
440	5.53 E2	9	10	LIRA

Friction Test - B (See Figure A-6 and A-7)

Dry material, 0.15% volatiles
Components: Tool steel/tool steel
Velocity 3.05 m/s

<u>Pounds-Force</u>	<u>Pressure, MPa**</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
175	3.06 E2	0	20	No reaction
245	3.80 E2	3	10	LIRA
440	5.53 E2	5	10	LIRA
620	6.90 E2	7	10	LIRA
840	8.38 E2	9	10	LIRA

*Kilo Joules per square meter.

**Mega Pascals.

TABLE A-II (CONT'D.)

ESD Test (See Figure A-8)

Dry material, 0.25% volatiles

<u>Energy, Joules</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
0.500	0	20	No reaction
1.260	1	10	LIRA
5.000	10	10	LIRA

CAAP SLUDGE
VAC DRIED POWDER
THRU 20 MESH

IMPACT

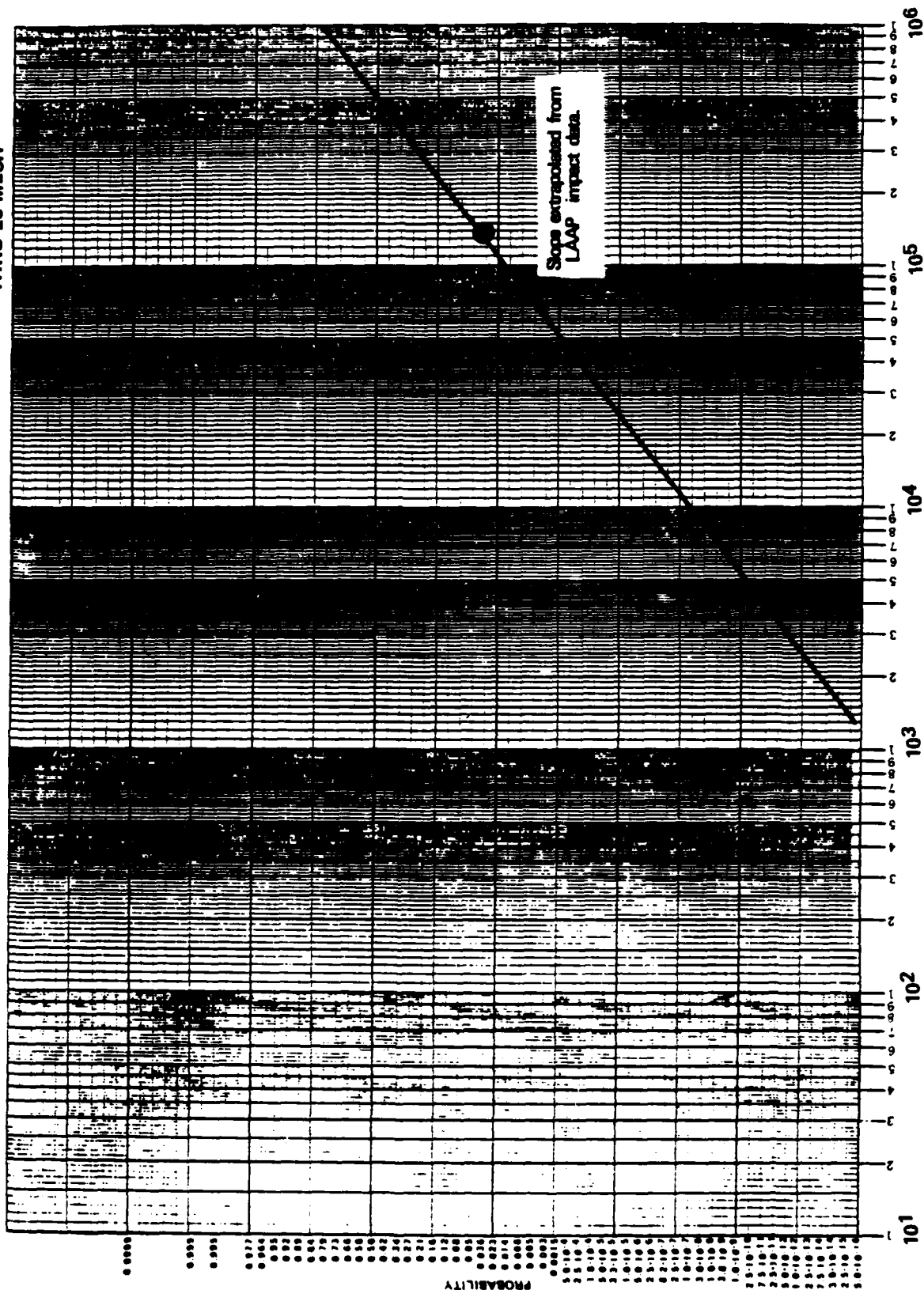


Figure A-5

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CAAP SLUDGE
VAC DRIED POWDER
THRU 20 MESH

FRICTION

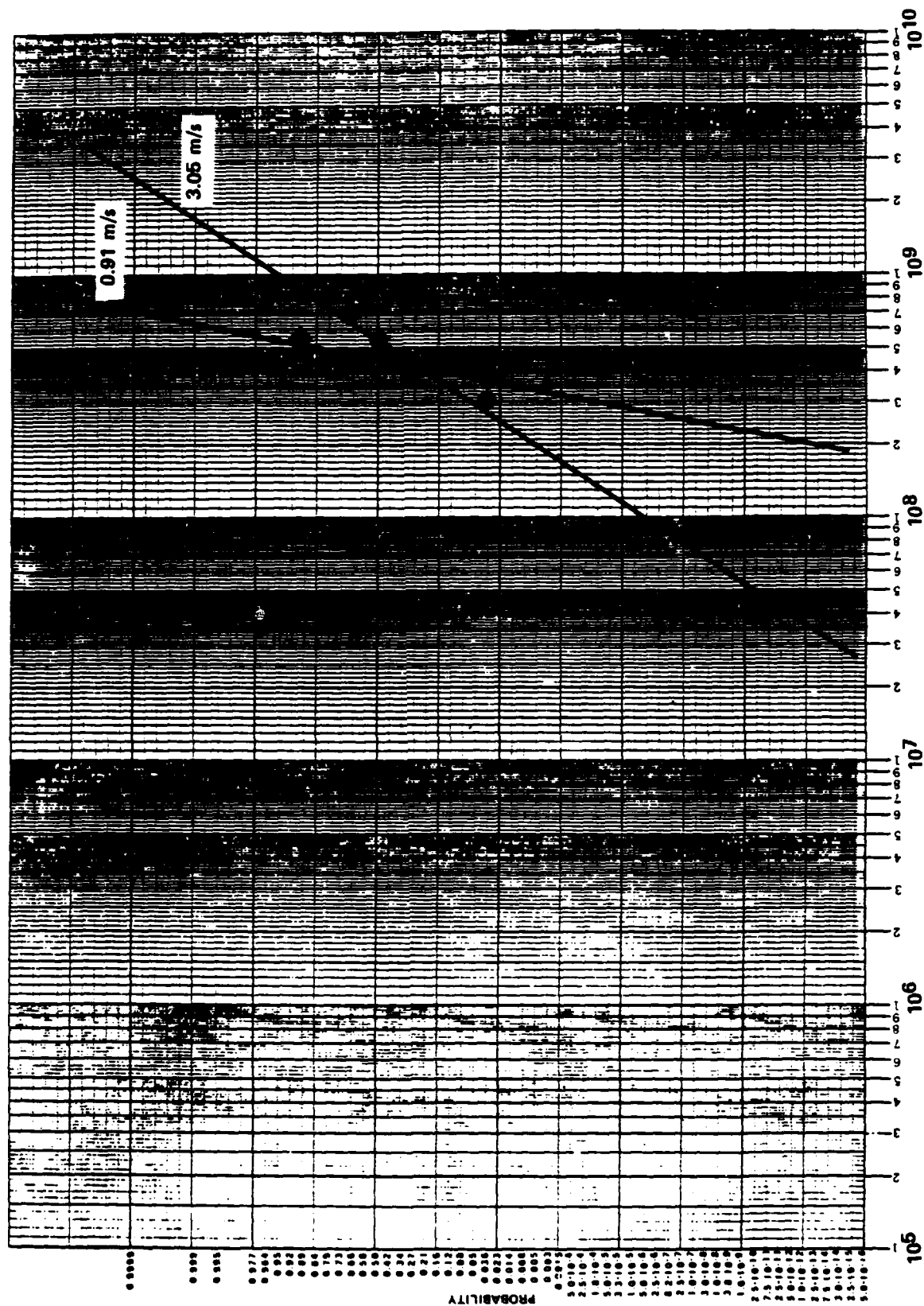


Figure A-6

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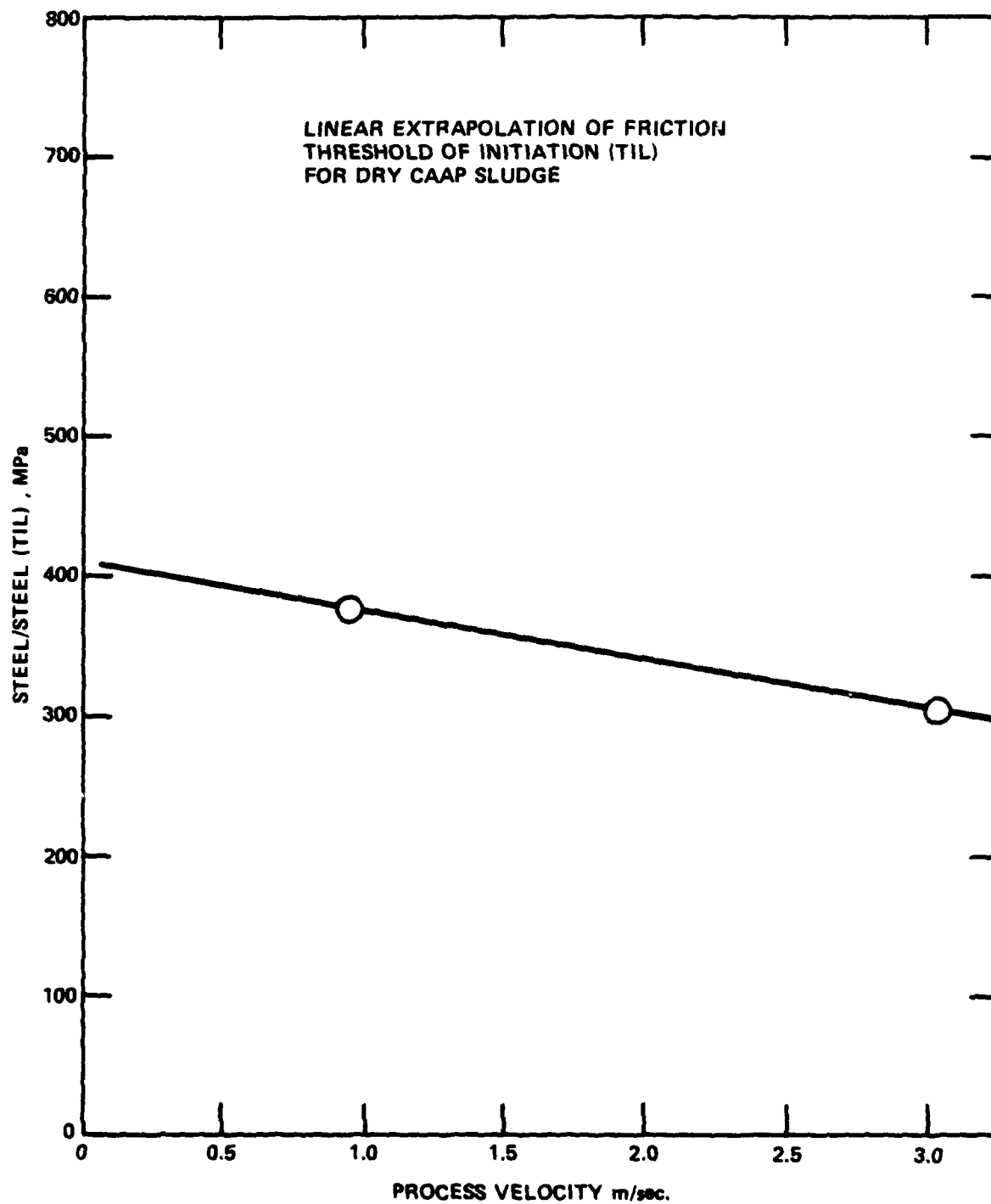


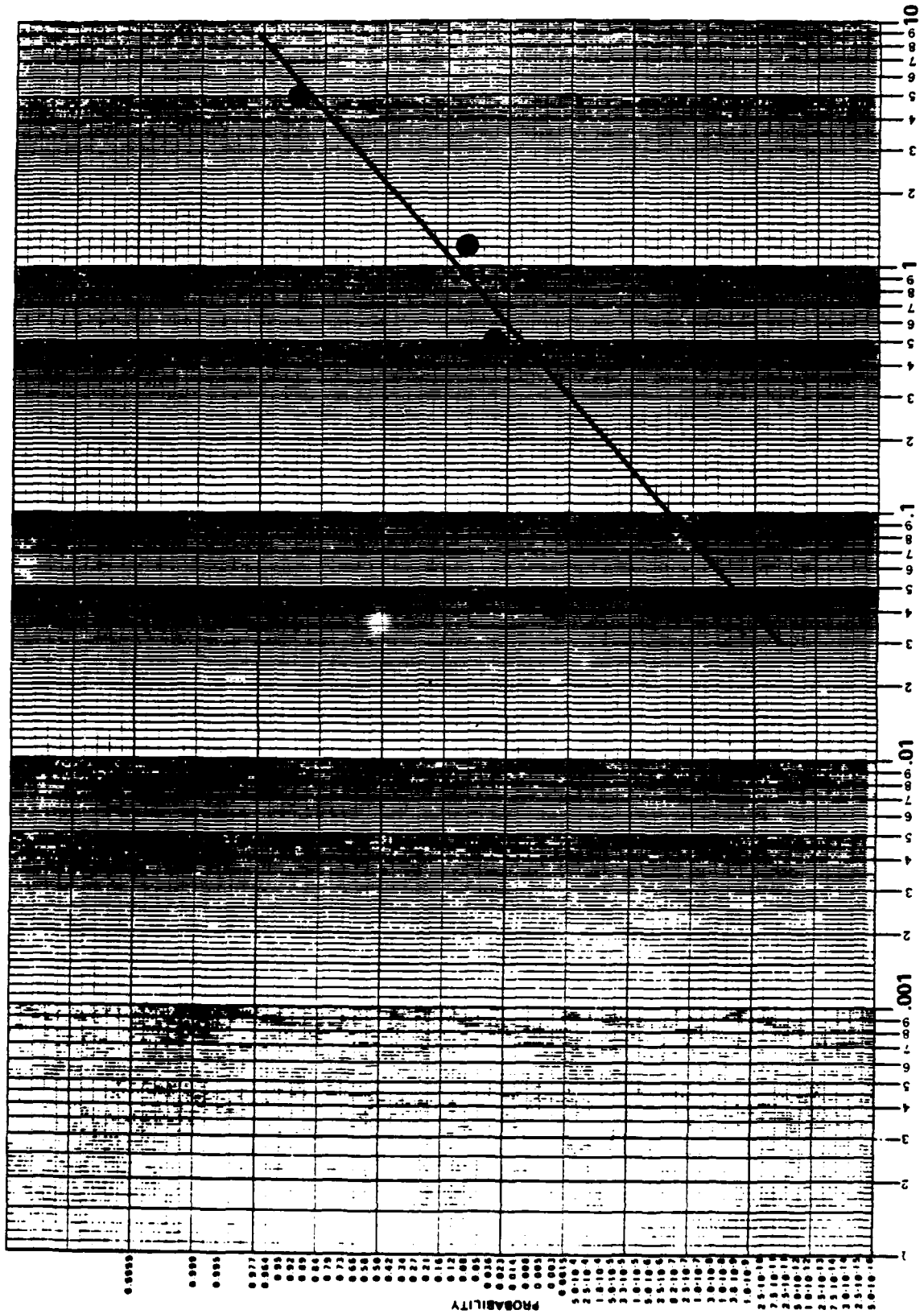
Figure A-7

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CAAP SLUDGE
VAC DRIED POWDER
THRU 20 MESH

ESD



Joules

Figure A-8

A-13

D-41

TABLE A-III

SENSITIVITY RESULTS
LOUISIANA ARMY AMMUNITION PLANT (LAAP) LAGOON SLUDGE

Impact Test - A (See Figure A-9)

Dry material, 0.28% volatiles
Components: Tool steel/tool steel.

<u>Height, cm</u>	<u>Energy, KJ/m²*</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
6.9	7.99	0	20	No reaction
17	1.97 E1	1	10	Noise, smoke, LIRA
33	3.82 E1	1	10	Noise, smoke, LIRA
41	4.75 E1	2	10	Noise, smoke, LIRA
51	5.91 E1	6	10	Noise, smoke, LIRA
80	9.26 E1	9	10	Noise, smoke, LIRA

Impact Test - B (See Figure A-9)

Damp material, 16.75% volatiles
Components: Tool steel/tool steel

<u>Height, cm</u>	<u>Energy, KJ/m²*</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
120	1.39 E2	0	20	No reaction

Friction Test - A (See Figure A-10 and A-11)

Dry material, 0.28% volatiles
Components: Tool steel/tool steel
Velocity 0.91 m/s

<u>Pounds-Force</u>	<u>Pressure, MPa**</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
400	5.21 E2	0	20	No reaction
580	6.61 E2	2	10	LIRA
720	7.59 E2	4	10	LIRA
840	8.38 E2	6	10	LIRA
980	9.26 E2	10	10	LIRA
1120	1.01 E3	10	10	LIRA

* Kilo Joules per square meter.

**Mega Pascals.

TABLE A-III (CONT'D.)

Friction Test - B (See Figure A-10 and A-11)

Dry material, 0.28% volatiles
 Components: Tool steel/tool steel
 Velocity 3.05 m/s

<u>Pounds-Force</u>	<u>Pressure, MPa**</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
115	2.34 E2	0	20	No reaction
295	4.28 E2	3	10	LIRA
365	4.92 E2	6	10	LIRA
395	5.16 E2	8	10	LIRA
580	6.61 E2	10	10	LIRA

ESD Test (See Figure A-12)

Dry material, 0.28% volatiles

<u>Energy, Joules</u>	<u>Shots</u>	<u>Trials</u>	<u>Reaction</u>
0.024	0	20	No reaction
0.975	6	10	Flame, Smoke, LIRA
0.500	10	10	Flame, Smoke, LIRA

**Mega Pascals.

LAAP SLUDGE
VAC. DRIED THRU
20 MESH

IMPACT

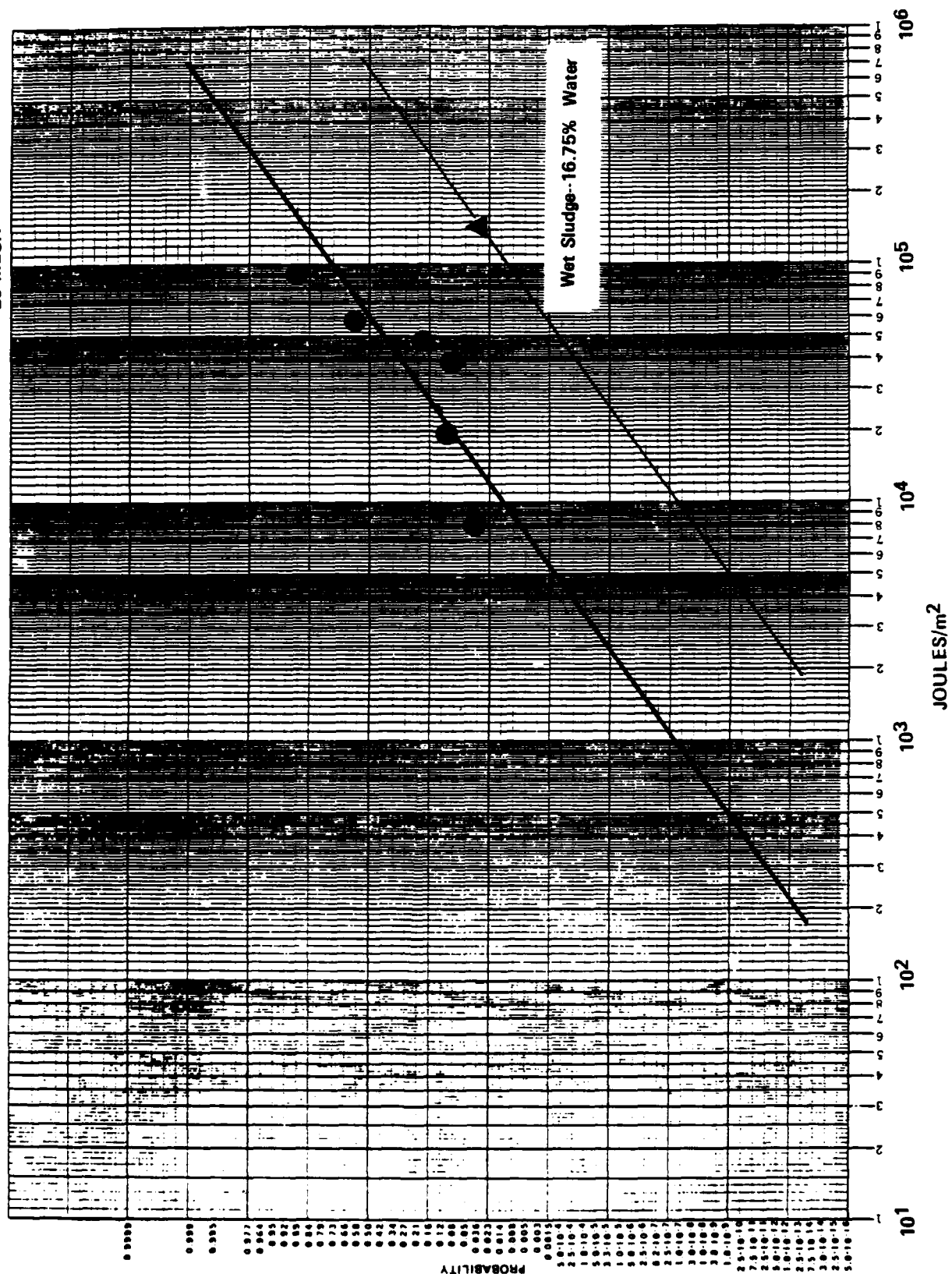


Figure A-9

A-16

D-44

LAAP SLUDGE
VAC DRIED THRU
20 MESH

FRICTION

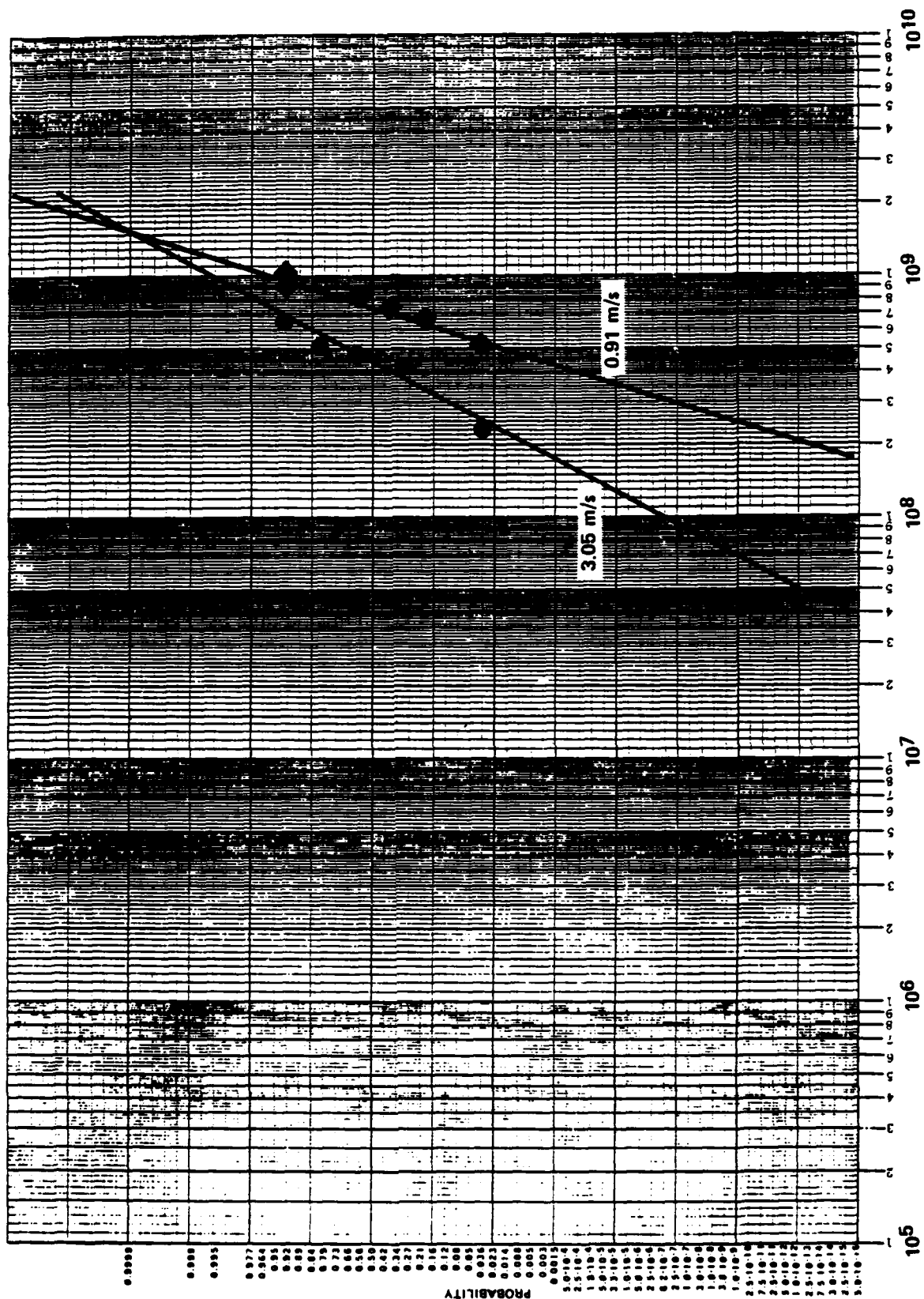


Figure A-10

A-17

D-45

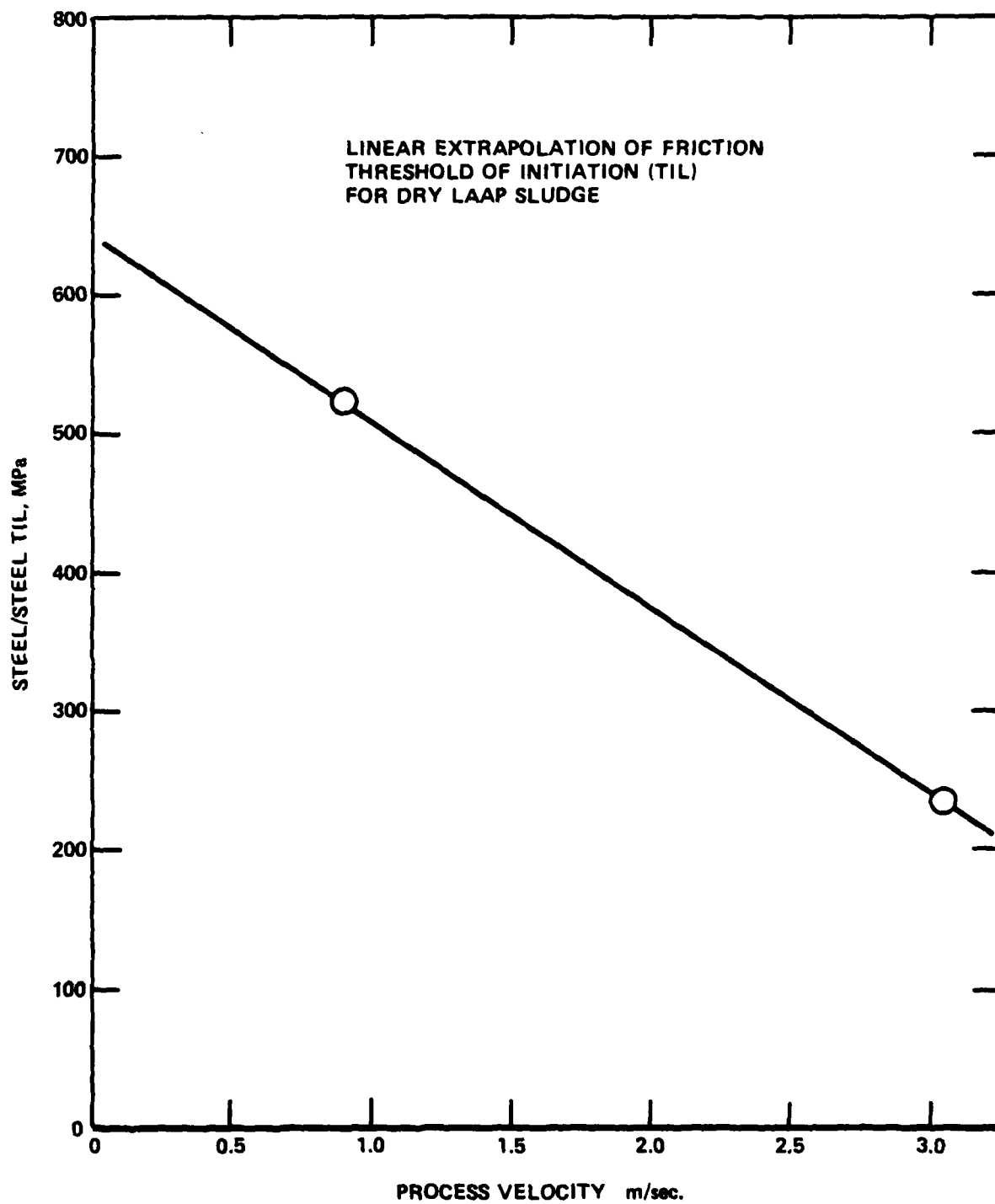


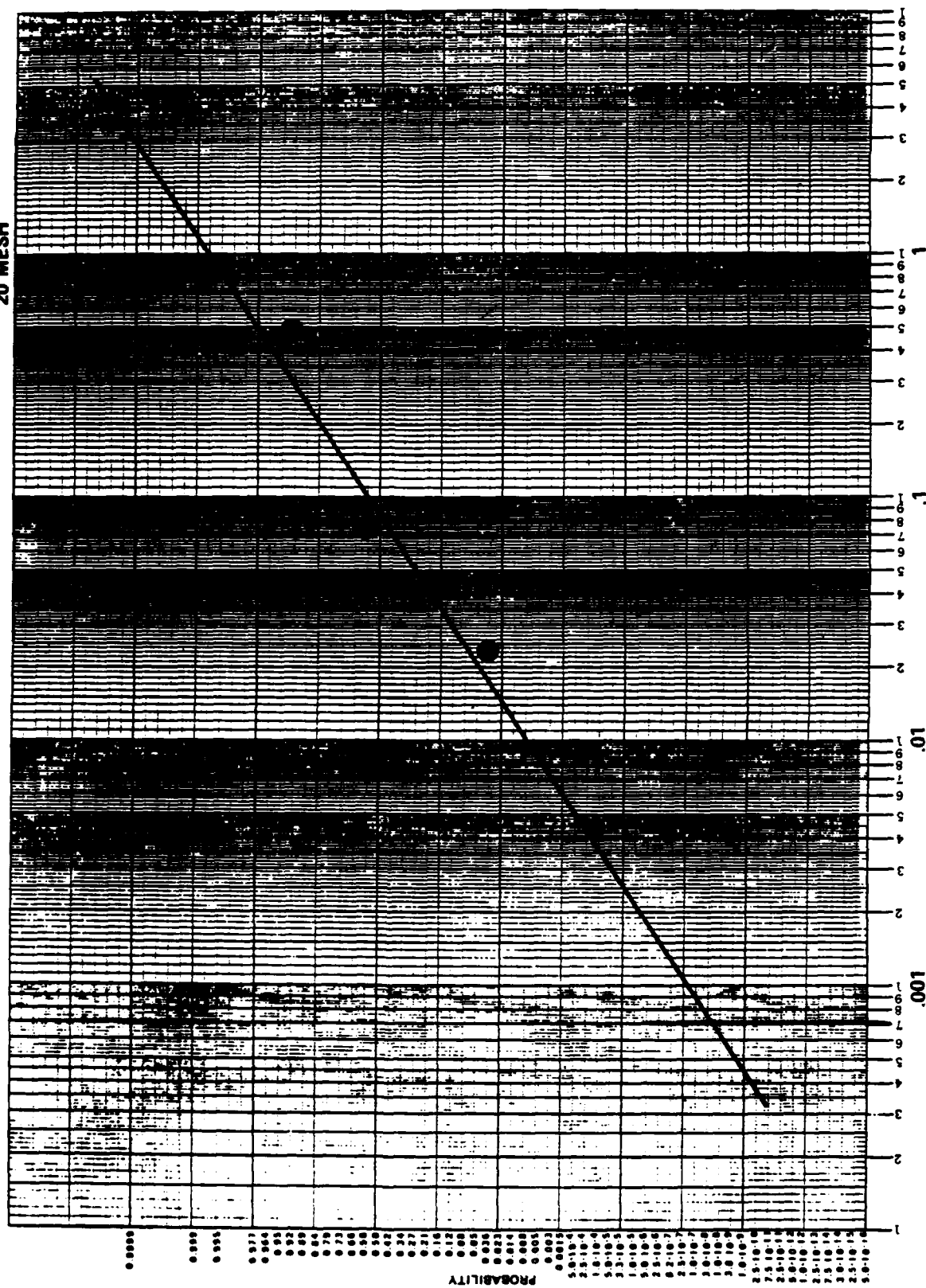
Figure A-11

A-18

D-46

LAAP SLUDGE
VAC. DRIED THRU
20 MESH

ESD



Joules
Figure A-12

A-19

D-47

APPENDIX A (CONT'D.)

B. SENSITIVITY SAMPLE PREPARATION AND TESTING

1. Preparation

All lagoon sludge materials were vacuum dried for at least 48 hours at 135°F. Total volatiles as determined by reheating 48 hours @ 135°F at the time of testing, showed the following values:

SADA	0.23%
CAAP	0.15%
LAAP	0.28%

Following the vacuum drying operation, the material was passed through a 20 mesh screen, material passing the screen was subjected to the sensitivity tests.

2. Friction Testing

Friction sensitivity testing was performed using the ABL Sliding Friction Machine, Figure A-13. In this machine, force is applied hydraulically through a stationary wheel to a sample resting on an anvil. A pendulum is used to propel the sliding anvil at a known velocity, perpendicular to the force vector. This arrangement allows duplication of frictional situations with respect to force, velocity, materials of construction, and environment.

For the sludge friction sensitivity tests, the materials of construction were MGR tool steel, operated at three feet/sec (0.91 m/s) and 10 feet/sec (3.05 m/s) across the face of the sample. Frictional pressures up to about 200,000 psi (1.4×10^9 Pa) can be exerted by the equipment. The results are reported as Pascals (Newtons/m²) after converting pounds force and the area of the slide.

Due to the lack of initiation sensory responses, flash, fire, smoke, noise, or stain, the LIRA Infrared Analyzer (Figure A-14) was used to detect products of combustion arising within the apparatus' housing.

The LIRA Infrared Analyzer, in this instance, is calibrated to respond to a 4 ppm increase of any or all of the usual products of combustion from explosives, carbon dioxide, carbon monoxide, and the oxides of nitrogen.

Tests consist of ten trials at each decreasing process potential until no evidence of initiation is determined either by lenses or the LIRA analyzer. At a level of no response, 20 trials are completed to provide a Threshold Initiation Level (TIL) corresponding to a .037 probability.⁽⁸⁾ These results provide a 50% confidence level.

3. Impact Testing

Impact sensitivity testing is conducted using a Bureau of Mines designed drop weight machine (Figure A-15). This device allows a two kilogram weight to strike a monolayer thick sample located between a hammer and an anvil. The drop height can be varied from 1.1 to 120 centimeters. The striker and the anvil pieces are MGR tool steel. A small clear plastic enclosure around the impact zone allows aspirating gases from this volume to the LIRA analyzer for detection of combustion products in those instances where no sensory stimuli are detected during the impact. Technicians are highly trained and must be able to differentiate between smoke arising from a reaction and dust arising from the impact force. Results are recorded as centimeters height for a drop and the observed results of the impact. The results are reported in Joules/m² based on the height, weight, and impact area. Trial numbers are based on obtaining ten trials at a process potential without any response in which instance an additional ten trials are conducted to obtain the zero out of 20 TIL value. A probit plot can be determined on semi-log probability graphs by plotting the number of reaction results out of 10 trials (probability) or 20 at the various process potentials.

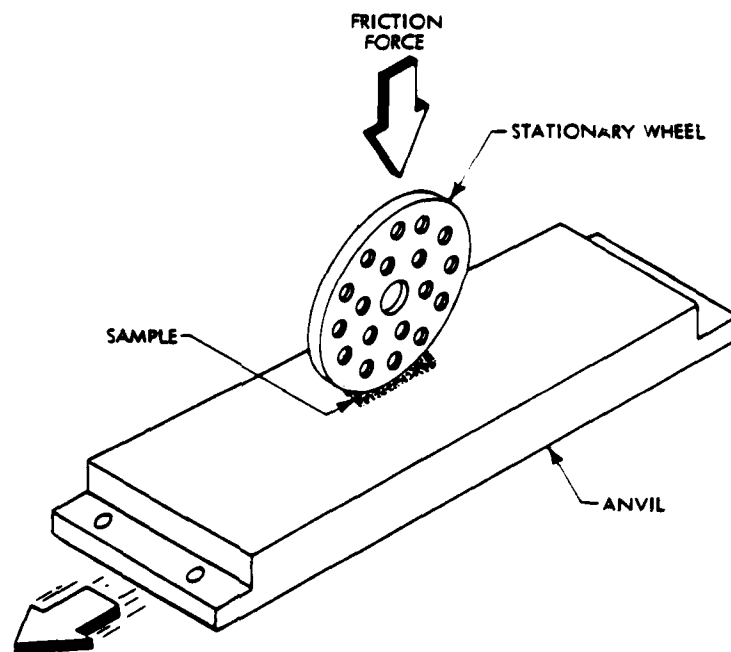
4. Electrostatic Discharge Testing

Electrostatic Discharge sensitivity testing is performed on an instrument of ABL design (Figure A-16) which allows charging certain size capacitors to a standard voltage and then discharging the capacitor's charge through the test sample. The range of energies available from the capacitor banks vary from 5 Joules to 0.0028 Joule. The energies are determined according to the following formula:

$$E = 1/2 C V^2$$

where: E is energy in Joules
C is capacitance in farads
V is voltage in volts

Again, ten trials at each energy level are performed until no reaction results are determined and an additional ten trials performed to determine the TIL level. The LIRA analyzer monitors for the products of combustion during this type test also. Results are recorded and reported as Joules.

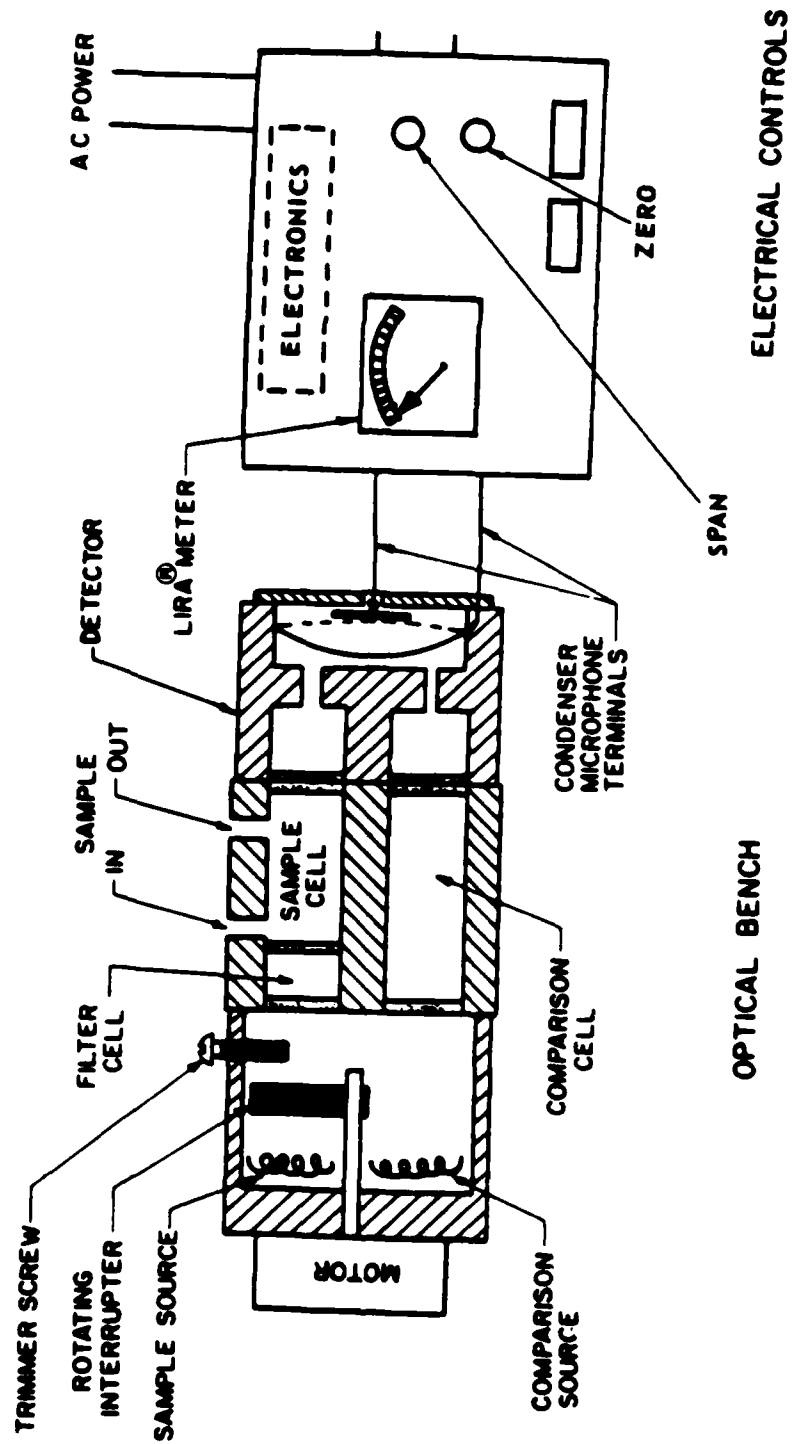


Friction Test Principle

Figure A-13

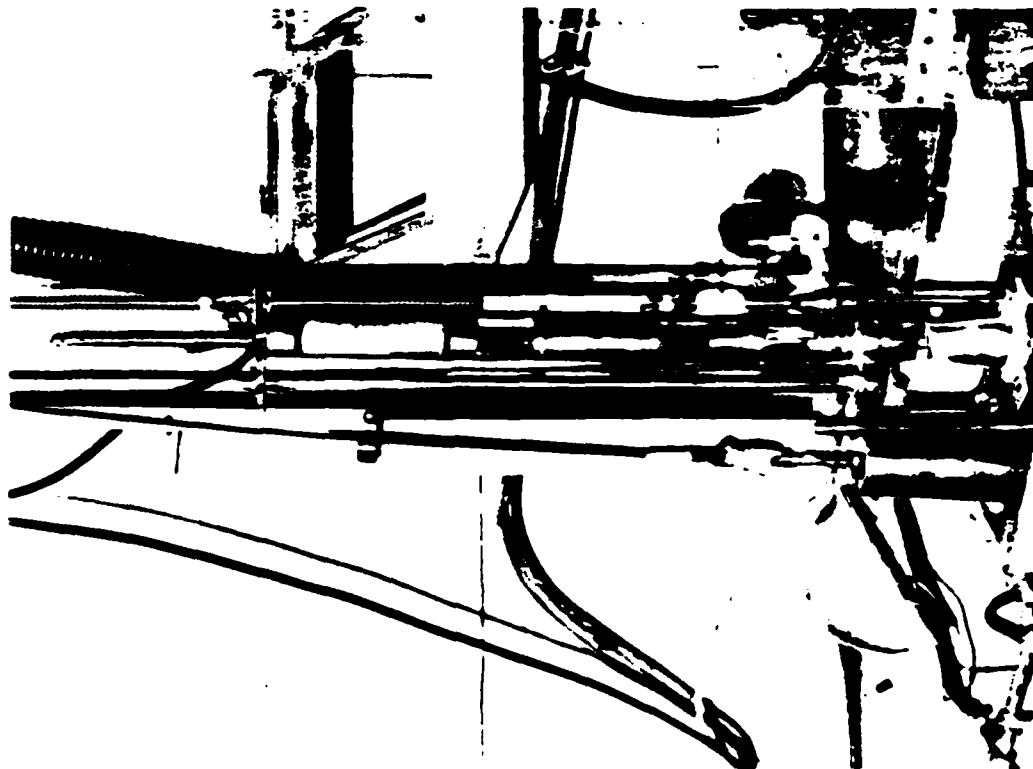
A-22

D-50

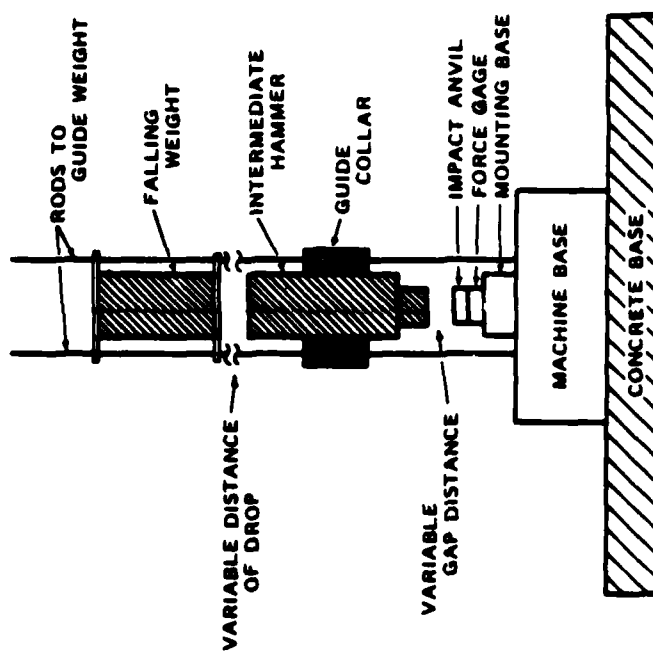


LIRA[®] INFRARED ANALYZER

Figure A-14

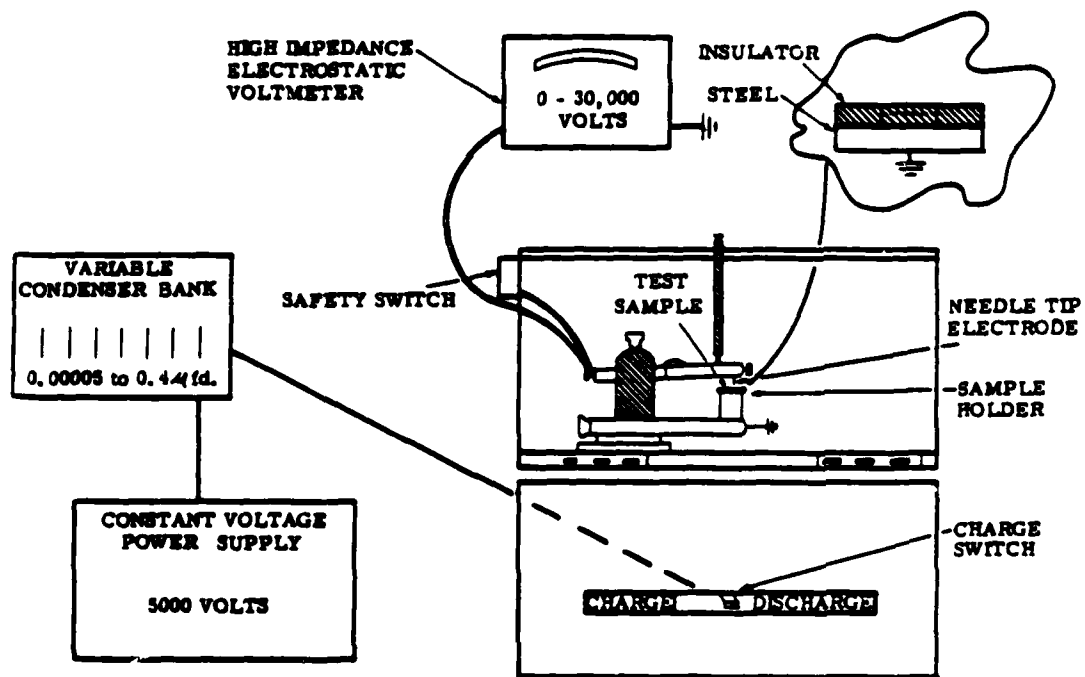


ABL Impact Machine
Figure A-15



A-24

D-52



ABL ELECTROSTATIC DISCHARGE MACHINE

Figure A-16

APPENDIX B

HAZARDS ANALYSIS OF
INCINERATION FEED SYSTEM

TABLE B-1

ENGINEERING ANALYSIS/HAZARD EVALUATION SHEET
HAZARDS ANALYSIS OF INCINERATION FEED SYSTEM

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
1. FEED HOPPER WITH LIVE BOTTOM											
4. Hopper Being Filled	Earthen material strikes lump breaker or earth or equipment strikes sides of hopper.										
	1. Rock or frozen or dried material, .016 m ³ or larger.	Impact Rock/steel	ECS (Explosive Contaminated Soil)	5.3 E5 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8.0 E3 J/m ²	Less than 1	Six drops x 1 E-3	1	.66	4 E-3	III α
						Less than 1	undetected rock or lump.		.52	3 E-3	
						Less than 1			.99	6 E-3	
	2. Near granular earth or rocks falling, 3 E-5 m ³ .	Impact Rock/steel	ECS	2.1 E3 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8.0 E3 J/m ²	57	Six drops		1 E-13	6 E-13	III α
						66		1	3 E-13	1.8 E-12	
						3.8			1 E-5	6 E-5	

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
1. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
A. Hopper Being Filled (Cont'd.)	3. Bump or bang hopper with dumper at 0.9 m/s.	Impact Steel/steel	ECS	1.3 E6 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8.0 E3 J/m ²	Less than 1 Less than 1 Less than 1	Six drops x E-3 accidental bump	.1	.92 .84 1.	5.5 E-4 5.0 E-4 6.0 E-4	II β
	4. Operator bangs hopper with sledge hammer to loosen material.	Impact Steel/steel	ECS	1.1 E4 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8.0 E3 J/m ²	11 13 Less than 1	1 E-3	1 (internally)	2.5 E-7 2.5 E-7 1.4 E-2	2.5 E-10 2.5 E-10 1.4 E-5	II β

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) (E _p)	MATERIAL PRESENT (C) (C _p)	INITIATION (I) (I _p)	FIRE (F) (F _p)	HAZARD CATEGORY
1. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
8. Hopper Bridges (Cont'd.)	1. (cont'd.)	Impact Steel/steel	ECS	2.5 E4 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8.0 E3 J/m ²	4.8 5.6 Less than 1	Bridge 1 E-2	1	4 E-5 3.5 E-5 .14	4 E-7 3.5 E-7 1.4 E-3	II β
	2. Operator attempts to clear with a crow bar.	Friction Steel/rock	ECS	1.1 E6 Pa at 0.9 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa at 0.9 m/s	411 355 486	Bridge 1 E-2	1	5 E-16 5 E-16 5 E-16	5 E-18 5 E-18 5 E-18	II β
		Friction Steel/steel	ECS	2.5 E8 Pa at 0.9 m/s max	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa at 0.9 m/s	1.8 1.5 2.1	Bridge 1 E-2	1	5 E-6 1 E-7 1 E-9	5 E-8 1 E-9 1 E-11	II β

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E _p)	MATERIAL PRESENT (C _p)	INITIATION (I _p)	FIRE (F _p)	HAZARD CATEGORY
1. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
B. Hopper Bridges (Cont'd.)	5. Operator attempts to clear hopper bridging and tool is dropped. (cont'd.)	Impact/Wood/steel	ECS	1.6 E4 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8 E3 J/m ²	7.5 8.8 Less than 1	Bridge 1 E-2, drop tool 1 E3	1	3 E-6 2.5 E-6	3 E-11 2.5 E-11	II β
C. Screws Receive Foreign Material During Feed	1. Tool or nut or bolt in fed earth.	Friction Steel/steel	ECS	3.1 E8 Pa at .07 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa at 0.9 m/s	1.4 1.2 1.7	Metallic foreign material 1 E-3	1	5 E-6 5 E-6 1 E-8	5 E-9 5 E-9 1 E-11	III α
	2. Tool dropped in hopper hitting breaker bar.	Impact Steel/steel	ECS	4.2 E4 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8 E3 J/m ²	2.9 3.3 Less than 1	Tool dropped 1 E-4	.1	5 E-4 3 E-4 .3	5 E-9 3 E-9 3 E-6	II β

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
I. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
C. Screws Receive Foreign Material During Feed (Cont'd.)	3. Stone in screw.	Friction Steel/stone	ECS	1.1 E6 Pa at .07 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa at 0.9 m/s	400 345 472	.1	1	5 E-16 5 E-16 5 E-16	5 E-17 5 E-17 5 E-17	III α
	4. Material packs against shroud dries, breaks up.	Friction Steel/earth	ECS	4.8 E5 Pa at .07 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa at 0.9 m/s	916 791 1083	1	1	5 E-16 5 E-16 5 E-16	5 E-16 5 E-16 5 E-16	III α
		Thermal increase	ECS	3.5°C/hr	TNT or RDX 100 hrs at 100°C	28 Time	1	1	2 E-11	2 E-11	III α

TABLE B-1 (CONT'D.)

		ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
OPERATION	POTENTIAL INITIATION HAZARD	INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
I. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
C. Screws Receive Foreign Material During Feed (Cont'd.)	8. Disassemble screws and a screw is scraped.	Friction Steel/steel	ECS	9.7 E6 Pa 0 .3 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa 0 .9 m/s	45 39 53	1 E-3 Jam 1 E-4 scrape	1 E-3 unit re-paired in con-taminated condition	5 E-16 5 E-16 5 E-16	5 E-26 5 E-26 5 E-26	I β
	9. Disassemble screws and a screw is dropped.	Impact Steel/steel	ECS	3.9 E5 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8 E3 J/m ²	Less than 1	1 E-3 Jam 1 E-4 drop	1 E-3 unit re-paired in con-taminated condition	.50 .42 .98	5 E-11 4 E-11 1 E-10	I β
D. Normal Operations Mechanical Failures	1. Tail bearing loosens and shaft deflects.	Friction Stellite/stellite	ECS	1.4 E9 Pa 0 .07 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa 0 0.9 m/s	Less than 1	2 E-8 bolt fails x .25 per bolt		1 1 1	5 E-9 5 E-9 5 E-9	II α

TABLE B-1 (CONT'D.)

		ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
OPERATION	POTENTIAL INITIATION HAZARD	INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
I. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
D. Normal Operations, Mechanical Failures (Cont'd.)	4. Ribbon posts loosen and flights rub.	Friction Stellite/stellite	ECS	1.4 E9 Pa 0 .07 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa 0 0.9 m/s	Less than 1 Less than 1 Less than 1 Less than 1	Failure 1 E-6 and unit fails to trip on overload 1 E-4		1 1 1	1 E-10 1 E-10 1 E-10	II α
		Thermal	ECS	12°C/hr	TNT or RDX 100 hrs at 100°C	8.3 Time	Failure 1 E-6 and unit fails to trip on overload 1 E-4	1	2.3 E-10	2.3 E-20	II α
E. Normal Operation	1. Heat generated during screw conveying.	Thermal	ECS	3.0°C/hr	TNT or RDX 100 hrs at 100°C	33 Time	Failure 1 E-6 and unit fails to trip on overload 1 E-4	1	1.2 E-11	1.2 E-11	III α

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) (E_p)	MATERIAL PRESENT (C) (C_p)	INITIATION (I) (I_p)	FIRE (F) (F_p)	HAZARD CATEGORY
1. FEED HOPPER WITH LIVE BOTTOM (CONT'D.)											
E. Normal Operation (Cont'd.)	2. Dust ignited by mechanical or electrostatic spark.	Mechanical spark	ECS dust	3.5 E-4 J	TNT .013 J	37	1 E-3	1 E-3 0 70 grams/ m^3	2.6 E-9	2.6 E-15	III α
		ESD	ECS dust	1.5 E-2 J. human developed	TNT .013 J	Less than 1	1 E-3	1 E-3 0 70 grams/ m^3	.11	1.1 E-7	II β
		Mechanical spark	ECS dust	3.5 E-4 J	HMX .024 J	68	1 E-3	1 E-5 0 470 gms/ m^3	3.3 E-9	3.3 E-17	III α
		ESD	ECS dust	1.5 E-2 J. human developed	HMX .024 J	1.6	1 E-3	1 E-5 0 470 gms/ m^3	4.8 E-4	4.8 E-12	II β

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
II. CROSS CON-VEYOR											
A. NORMAL OPERATION	1. Stone in screw.	Friction Steel/steel	ECS	1.1 E6 Pa 0 .23 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP	400 345	.1	1	5 E-16 5 E-16 5 E-16	5 E-17 5 E-17 5 E-17	II α
					5.2 E8 Pa 0 0.9 m/s	472					
		Impact Steel/stone	ECS	6.5 E3 J/m ²	SADA 1.2 E5 J/m ²	18			3.8 E-9	3.8 E-11	
					CAAP 1.4 E5 J/m ²	21	.1 Present	1	3.8 E-9	3.8 E-11	II α
					LAAP 8 E3 J/m ²	Less than 1	.1 metal contact		3 E-3	3 E-5	
	2. Heat generated during screw conveying.	Thermal	ECS	5.6°C/hr	TNT or RDX 100 hrs at 100°C	18 Time	1	1	2.7 E-11	2.7 E-11	II α

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
II. CROSS CONVEYOR (CONT'D.)											
B. Foreign Material Left in After Repair	1. Tool left in conveyor after repair.	Friction Steel/stellite	ECS	3.1 E8 Pa Ø .23 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa Ø 0.9 m/s	1.4 1.2 1.7	1 E-3 tool left and unit does not trip 1 E-4	1	2.5 E-6 3.3 E-5 3 E-8	2.5 E-13 3.3 E-12 3 E-15	II α
C. Mechanical Failures	1. Bearing fails and shaft deflects.	Friction Stellite/stellite	ECS	1.4 E9 Pa Ø .23 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa Ø 0.9 m/s	Less than 1 Less than 1 Less than 1 Less than 1 Less than 1 Less than 1	20 E-6 bearing fails x .33 per bearing and not alarmed 1 E-3	1	1 1 1	6.6 E-9 6.6 E-9 6.6 E-9	II α
	2. Ribbon post loosens and flights rub.	Friction Stellite/stellite	ECS	1.4 E9 Pa Ø .23 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa Ø 0.9 m/s	Less than 1 Less than 1 Less than 1 Less than 1 Less than 1 Less than 1	Failure 1 E-6 and unit fails to trip on overload 1 E-4	1	1 1 1	1 E-10 1 E-10 1 E-10	II α

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E _p)	MATERIAL PRESENT (C _p)	INITIATION (I _p)	FIRE (F _p)	HAZARD CATEGORY
II. CROSS CON-VEYOR (CONT'D.)											
C. Mechanical Failures (Cont'd.)	3. Thermal increase due to bearing or post failures.	Thermal	ECS	12°C/hr	TNT or RDX 100 hrs at 100°C	8.3 Time	6.6 E-6	1	2.3 E-10	1.5 E-15	II α
	4. Clean out and re-pair (refer to I.C.8 or .9.				SADA 1.2 E5 J/m ²					5 E-11	
					CAAP 1.4 E5 J/m ²					4 E-11	I β
					LAAP 8 E3 J/m ²					1 E-10	
III. JACKETED SCREW CON-VEYOR											
A. Normal Operation	1. Stone in screw.	Friction Inconel/stone	ECS	1.1 E6 Pa Ø .23 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa Ø 0.9 m/s	400 345 472	.1	1	5 E-16	5 E-17	II α

TABLE B-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR					HAZARD CATEGORY	
		INITIATION MODE	COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p			
III. JACKETED SCREW CONVEYOR (CONT'D.)													
A. Normal Operation (Cont'd.)	1. Stone in screw. (cont'd.)	Impact Inconel/stone	ECS	2.2 E4 J/m ²	SADA	5.5			3.3 E-5	3.3 E-7			
					1.2 E5 J/m ²		Rock present						
					CAAP 6.4		.1 metal contact	1			1 E-5	1 E-7	II α
					1.4 E5 J/m ²								
					LAAP Less than 1		.12						
					8 E3 J/m ²								

TABLE 8-1 (CONT'D.)

OPERATION	POTENTIAL INITIATION HAZARD	ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
		INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
III. JACKETED SCREW COMVEYOR (CONT'D.)											
C. Mechanical Failures	1. Hanger bearing falls.	Friction	ECS	3.7 E8 @ .23 m/s	SADA	1.2			5 E-5	3 E-10	
		Inconel/stellite			4.4 E8 Pa						
					CAAP	1.0	6 E-4	1 E-2	3 E-3	1.8 E-8	II α
					3.8 E8 Pa						
					LAAP	1.4			5 E-6	3 E-11	
	2. Bearing hanger falls, or flights loosen.				5.2 E8 Pa						
					0 0.9 m/s						
		Friction	ECS	1.4 E9 @ .23 m/s	SADA	Less	1 E-6 and unit				
		Stellite/stellite			4.4 E8 Pa	than 1					
					CAAP	Less	falls to trip on overload	1	1	1 E-10	II α
					3.8 E8 Pa	than 1					
					LAAP	Less					
					5.2 E8 Pa	than 1	1 E-4				
					0 0.9 m/s						
		Thermal	ECS	12°C/hr	TNT or RDX 100 hrs at 100°C	18 Time	1	1	2.7 E-11	2.7 E-11	II α

TABLE B-1 (CONT'D.)

		ENGINEERING ANALYSIS					PROBABILITIES/HOUR				
OPERATION	POTENTIAL INITIATION HAZARD	INITIATION MODE	COMBUST.	POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	HAZARD CATEGORY
III. JACKETED SCREW CONVEYOR (CONT'D.)											
C. Mechanical Failures (Cont'd.)	3. Repair and screw is scrapped on removal.	Friction Stellite/Inconel	ECS	3.7 E8 @ .3 m/s	SADA 4.4 E8 Pa CAAP 3.8 E8 Pa LAAP 5.2 E8 Pa @ 0.9 m/s	1.2 1.0 1.4	1 E-3 repair and 1 E-4 screw is scrapped	1 E-3	5 E-5 3 E-3 5 E-6	5 E-15 3 E-13 5 E-16	1 β
		Impact Stellite/Inconel	ECS	3.9 E4 J/m ²	SADA 1.2 E5 J/m ² CAAP 1.4 E5 J/m ² LAAP 8.0 E3 J/m ²	3.1 3.6 Less than 1	1 E-3 repair and 1 E-4 screw is dropped	1 E-3	7.5 E-11 7.5 E-11 2.5 E-4	7.5 E-21 7.5 E-21 2.5 E-14	1 β

TABLE 8-1 (CONT'D.)

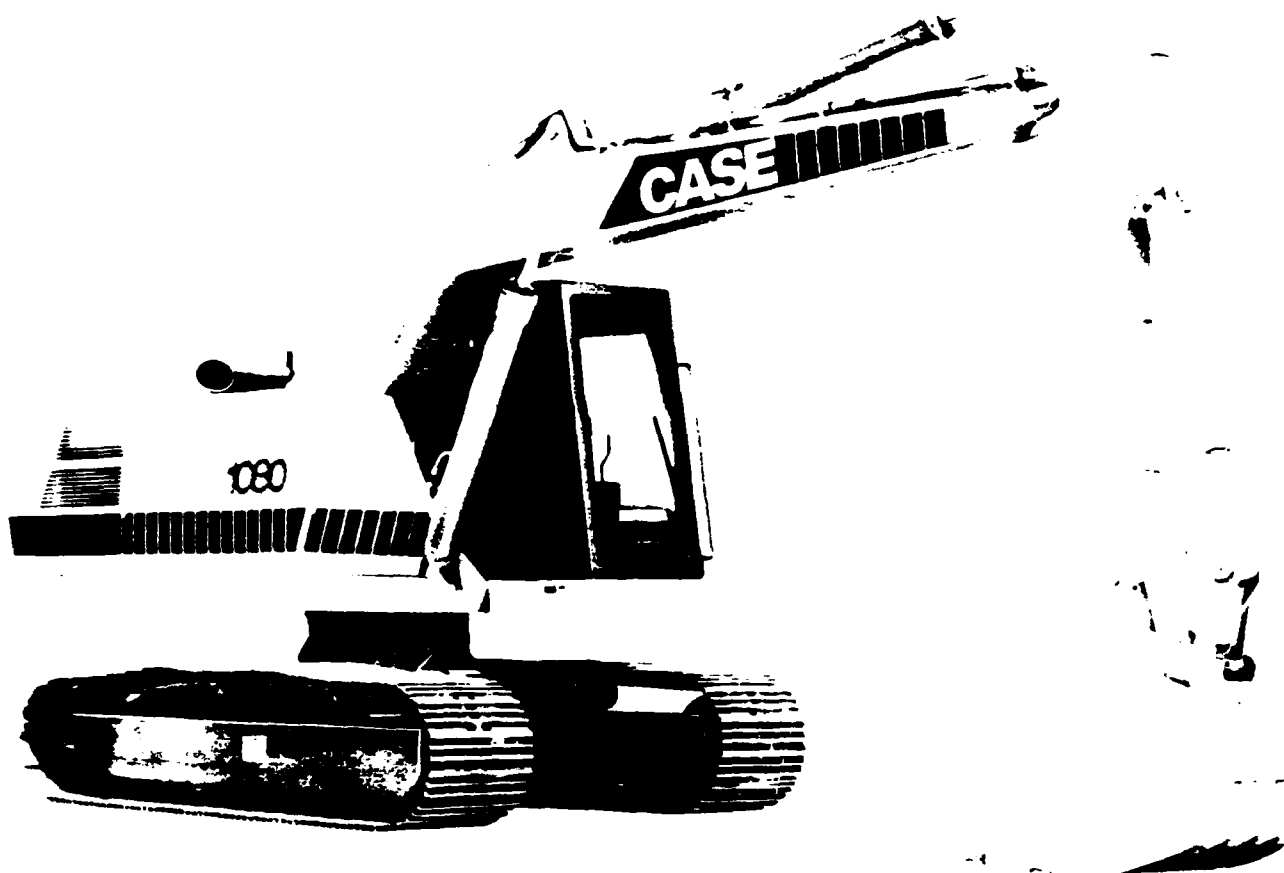
OPERATION	POTENTIAL INITIATION HAZARD	INITIATION MODE	ENGINEERING ANALYSIS				PROBABILITIES/HOUR				HAZARD CATEGORY
			COMBUST.	PROCESS POTENTIAL	MATERIAL RESPONSE	SAFETY MARGIN	EVENT (E) _p	MATERIAL PRESENT (C) _p	INITIATION (I) _p	FIRE (F) _p	
IV. CLEAN-UP	1. Spill has air dried and is shovelled up with non-sparking metal tools.	Impact Aluminum bronze vs. rock	ECS	4.1 E4 J/m ²	SADA	2.9	.1 rock	1	5 E-4	5 E-6	II β
					1.2 E5 J/m ²		x .1 dried				
					CAAP		.1 rock				
					1.4 E5 J/m ²		x .1 dried				
					LAAP		.1 rock				
					8 E3 J/m ²		x .1 dried				
		Friction Aluminum bronze vs. rock	ECS	6.5 E7 Pa 0 .9 m/s max	SADA	6.8	.1 rock	1	5 E-16	5 E-18	II β
					4.4 E8 Pa		x .1 dried				
					0 .9 m/s						
					CAAP		.1 rock				
					3.6 E8 Pa		x .1 dried				
					0 .9 m/s						
					LAAP		.1 rock				
					5.2 E8 Pa		x .1 dried				
					0 .9 m/s						

APPENDIX E
CATALOG DATA FOR THE TRACKED EXCAVATOR

0492B



1080 Crawler Excavator



55 gal (208 L) total system capacity.

Maintenance free rollers and idlers. Travel speed up to 2.4 mph (3.87 km/h) w/ optional 2-speed drive.

Featuring stowable front window and easy logical control systems to assure operator efficiency.

Allows the upperstructure to tilt 8° right or left.

Unit shown is equipped with non-standard items.

J I Case

A Tenneco Company



Construction Equipment Division
700 State Street Racine, WI 53404 U.S.A.

SPECIFICATIONS 1080 CRAWLER EXCAVATOR

GENERAL

Make and Model	Case A504 BDT Diesel or Detroit Diesel 4-71 N
Fuel	No. 2 diesel
No. of cylinders	6
Case A504 BDT	6
Detroit Diesel 4-71 N	4
Bore and Stroke	
Case A504 BDT	4.625" x 5" (117.4 mm x 127 mm)
Detroit Diesel 4-71 N	4.25" x 5" (107.95 mm x 127 mm)
Displacement	
Case A504 BDT	504 in ³ (8 259 cm ³)
Detroit Diesel 4-71 N	284 in ³ (4 654 cm ³)
Fuel induction	
Case A504 BDT	Injectors (6)
Detroit Diesel 4-71 N	Injectors (4)
Fuel supply	
Case A504 BDT	Low pressure transfer pump
Detroit Diesel 4-71 N	Pos. displacement gear-type pump
Air cleaner	Dry type
Oil filter	Renewable cartridge
Lubrication	Positive pressure
Cooling system	Pressurized radiator and lubricated bearing impeller pump
Horsepower	
Case A504 BDT	
(1) Gross (SAE)	170 @ 2100 rpm (127 kW @ 2100 rpm)
(2) Net (SAE)	153 @ 2100 rpm (114 kW @ 2100 rpm)
Detroit Diesel 4-71 N	
(1) Gross (SAE)	157 @ 2300 rpm (117 kW @ 2300 rpm)
(2) Net (SAE)	143 @ 2300 rpm (107 kW @ 2300 rpm)
Torque, maximum (SAE)	
Case A504 BDT	485 lbs.-ft. @ 1600 rpm (658 Nm @ 1600 r/min)
Detroit Diesel 4-71 N	400 lbs.-ft. @ 1600 rpm (542.33 Nm @ 1600 r/min)
(1) Gross engine horsepower or torque at flywheel per SAE J270 specification	
(2) Net engine horsepower or torque at flywheel per SAE J270 specification	

ELECTRICAL

Starting	24 volt electric
Batteries (2)	625 CCA @ 0° F (-18° C) at 30 sec rate
Alternator	42 amp

HYDRAULIC SYSTEM

Pumps: Tandem gear-type pumps rated at: 393	
Case A504 BDT	104 gpm (393 L/min) @ 2100 rpm
Detroit Diesel 4-71 N	109 gpm (412 L/min) @ 2300 rpm
Relief valve pressure setting (total summated system)	3000 psi (20 647 kPa)
Oil cooler: Positive, radiator type oil cooler located in front of engine eliminates need for excessive amount of oil, keeps oil at optimum operating temperature.	
Control valves: Mono-block, self-centering.	
Cylinders: Double-acting hydraulic cylinders for hoist, crowd, boom, swing and auxiliary fast hoist:	
Boom cylinder	6.5" x 54.5" (165 mm x 1 38 m)
Dipper cylinder	6.5" x 47.5" (165 mm x 1 21 m)
Bucket cylinder	5.5" x 38.0" (140 mm x 914 mm)

Cylinders: Single-acting hydraulic cylinders for leveler and track adjusting	
Leveler cylinder	6.25" x 59 mm
Track adjusting cylinder	3.0" x 76 mm

Cylinder cycle time: - Case 504 BDT

Hoist cylinder (full stroke)	
Extended	3.0 sec
(with last hoist feature)	4.5 sec
Retracted	5.6 sec
Crowd cylinder (full stroke)	
Extended	7.8 sec
Retracted	
E Boom	4.9 sec
Y Boom	5.6 sec
Bucket cylinder (full stroke)	
Extended	4.3 sec
Retracted	2.5 sec

Swing system: 360° hydraulic swing system has positive operator control with combination of hydraulic motor, disc brake and 22:1 gear reducer. Brake provides positive swing lock when setting or swinging heavy pipe, or when transporting.

Swing: Continuous @ 6.1 rpm

Track drives: Fully independent. Each track features hydraulic drive motor, integral disc braking system and completely enclosed final drive gear box.	
Track adjustment	Hydraulic
Track effort (Drawbar pull)	
Standard	32 320 lbs (19 2 kN)
Optional	43 450 lbs (133.3 kN)

CRAWLER UNDERCARRIAGE

Track length	125' 3.8" (m)
Track gauge	75' 2.26" (m)
Track height	2' 1" 889 mm
Track pad width	
Standard	24" 610 mm
Optional	30" 762 mm
Track rollers (per side) permanently sealed	8
Top carrier rollers (per side)	2
Crawler track speed	
Standard single-speed	Infinite to 1.5 mph (2.42 km/h)
Optional 2-speed	Infinite to 2.4 mph (3.87 km/h)
*Gradeability	60%
Ground pressure	
24" (610 mm) standard shoes	6.6" psi (45.59 kPa)
30" (762 mm) optional shoes	5.29 psi (36.49 kPa)

*Gradeability is a measure of the tractive effort only and does not represent grades on which the machine can operate.

SERVICE CAPACITIES

	U.S.	Litres
Fuel tank	75 gals	284
Hydraulic system (complete)	55 gals	208
Hydraulic reservoir	25 gals	95
Drive transmissions (each)	12 qts	11.4
Swing gearbox	17 qts	16.1
Engine crankcase (w/filter) - Case A504 BDT	23 qts	21.7
Engine crankcase (w/filter) - Detroit 4-71 N	16 qts	15.2
Cooling system	8.5 gals	32.2

WEIGHTS

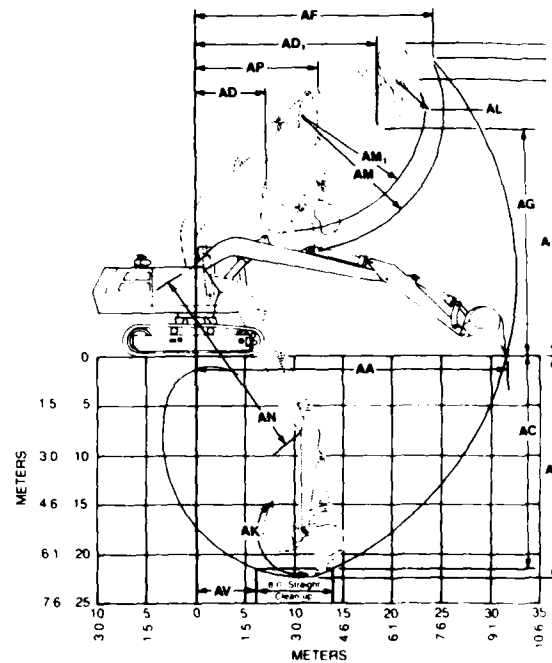
*Operating weight	40 950 lbs (18 575 kg)
Leveler weight	1 098 lbs (498 kg)
Counterweight	8 650 lbs (3 924 kg)

*NOTE: Unit equipped with 1 200 lbs (544 kg) bucket, 9' (2.74 m) dipperstick, 24" (610 mm) shoes, leveler and counterweight.

OPERATING DATA - "E" BOOM

	9' (2.74 m) DIPPER	10'5" (3.17 m) DIPPER
AA Maximum reach at grade level	30'5" (9.27 m)	31'10" (9.70 m)
AB Maximum digging depth (tip of teeth)	21'0" (6.40 m)	22'5" (6.83 m)
AC Maximum depth of cut for 8' (2.44 m) level bottom (straight clean-up)	20'6" (6.25 m)	21'11" (6.68 m)
AD Radius of bucket teeth at maximum boom elevation — dipperstick and bucket swing fully in	6'1" (1.85 m)	5'11" (1.80 m)
AD ₁ Radius of bucket teeth at maximum boom elevation — dipperstick fully extended, bucket swing fully in	17'5" (5.31 m)	18'6" (5.64 m)
AE Minimum vertical clearance of bottom of dipper from grade at max. boom elevation	11'0" (3.35 m)	9'8" (2.95 m)
AF Maximum clearance of bucket teeth at maximum boom elevation	22'3" (6.78 m)	23'5" (7.14 m)
AG Minimum vertical clearance of bucket teeth from grade with attachment at max. height	22'3" (6.78 m)	23'0" (7.01 m)
AG ₁ Vertical clearance of bucket teeth relative to dimension AF	26'6" (8.08 m)	27'5" (8.36 m)
AH Bucket teeth distance from grade at end of highest dump	29'0" (8.84 m)	29'6" (8.99 m)
AJ Maximum height of attachment	30'3" (9.22 m)	30'11" (9.42 m)
AK Bucket sweep angle	131° & 158°	131° & 158°
AL Bucket sweep radius	4'4" (1.32 m)	4'4" (1.32 m)
AM Dipperstick sweep radius over teeth — extended	13'4" (4.06 m)	14'9" (4.50 m)
AM ₁ Dipperstick sweep radius — retracted	11'7" (3.53 m)	12'11" (3.94 m)
AN Boom length from boom hinge pin to dipperstick pin	19'8" (5.99 m)	19'8" (5.99 m)
AO Vertical clearance for highest dumping sweep of bucket teeth	9'3" (2.82 m)	7'10" (2.39 m)
AP Maximum attachment radius with boom at maximum elevation and dipper- stick and bucket swing fully in	11'6" (3.51 m)	11'3" (3.43 m)
AV Minimum radius of 8' (2.44 m) level bottom at maximum depth	8'9" (2.67 m)	8'9" (2.67 m)

NOTE: For units equipped with turntable leveler, add 5.5" (140 mm) to all above ground dimensions and subtract 5.5" (140 mm) from all below ground dimensions



9' Stick	17,420 lbs (7,902 kg)
10'5" Stick	15,710 lbs (7,126 kg)
Bucket (131° Rotation)	27,780 lbs (12,600 kg)
Bucket (158° Rotation)	22,715 lbs (10,303 kg)

Above & Below Groundline Dimensions	Distance from centerline of rotation							
	10' (3.05 m)		15' (4.57 m)		20' (6.10 m)		25' (7.62 m)	
	Side	End	Side	End	Side	End	Side	End
+ 10' (3.05 m)	14,800 lbs (6,713 kg)	14,800 lbs (6,713 kg)	9,600 lbs (4,354 kg)	9,600 lbs (4,354 kg)	7,400 lbs (3,357 kg)	7,400 lbs (3,357 kg)	*5,700 lbs (2,585 kg)	6,100 lbs (2,767 kg)
+ 5' (1.52 m)	12,500 lbs (5,670 kg)	12,500 lbs (5,670 kg)	11,000 lbs (4,990 kg)	11,000 lbs (4,990 kg)	*7,800 lbs (3,538 kg)	8,000 lbs (3,629 kg)	*5,500 lbs (2,495 kg)	6,300 lbs (2,858 kg)
Groundline 0	14,000 lbs (6,350 kg)	14,000 lbs (6,350 kg)	11,400 lbs (5,171 kg)	11,400 lbs (5,171 kg)	*7,500 lbs (3,402 kg)	8,300 lbs (3,765 kg)	*5,400 lbs (2,449 kg)	*6,200 lbs (2,812 kg)
- 5' (1.52 m)	15,400 lbs (6,985 kg)	15,400 lbs (6,985 kg)	11,000 lbs (4,990 kg)	11,000 lbs (4,990 kg)	*7,300 lbs (3,311 kg)	8,000 lbs (3,629 kg)	*5,300 lbs (2,409 kg)	5,900 lbs (2,676 kg)
- 10' (3.05 m)	13,000 lbs (5,897 kg)	13,000 lbs (5,897 kg)	9,500 lbs (4,309 kg)	9,500 lbs (4,309 kg)	*6,900 lbs (3,130 kg)	6,900 lbs (3,130 kg)	—	—

NOTE: Lifting capacities based on unit with "E" boom 24 (610 mm) track shoes and 9 (2.74 m) "E" boom dipperstick. Capacities include 1,200 lbs (544 kg) 24 (610 mm) bucket. All specifications comply with SAE J1097. Rated loads do not exceed 87% of hydraulic capacity or 75% of stability.

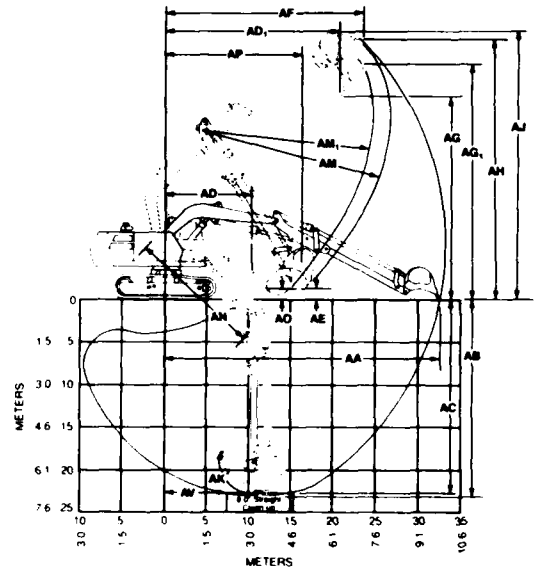
Weight of machine, equipped as shown above, is 40,950 lbs (18,575 kg).

*Indicates Tip

OPERATING DATA - "Y" BOOM

	EXTENSION EXTENDED	EXTENSION RETRACTED
AA Maximum reach at grade level	32' 8" (9.96 m)	28' 6" (8.69 m)
AB Maximum digging depth (tip of teeth)	23' 1" (7.04 m)	18' 9" (5.72 m)
AC Maximum depth of cut for 8' (2.44 m) level bottom (straight clean-up)	22' 9" (6.93 m)	18' 3" (5.56 m)
AD Radius of bucket teeth at maximum boom elevation — dipper arm and bucket swing fully in	8' 11" (2.72 m)	6' 7" (2.01 m)
AD ₁ Radius of bucket teeth at maximum boom elevation — dipper arm fully extended, bucket swing fully in	19' 4" (5.89 m)	15' 6" (4.72 m)
AE Minimum vertical clearance of bottom of dipper from grade at maximum boom elevation	1' 2" (356 mm)	5' 0" (1.52 m)
AF Maximum clearance of bucket teeth at maximum boom elevation	23' 10" (7.26 m)	19' 11" (6.07 m)
AG Minimum vertical clearance of bucket teeth from grade with attachment at maximum height	23' 9" (7.24 m)	21' 9" (6.63 m)
AG ₁ Vertical clearance of bucket teeth relative to dimension AF	28' 0" (8.53 m)	26' 1" (7.95 m)
AH Bucket teeth distance from grade at end of highest dump	30' 7" (9.32 m)	28' 9" (8.76 m)
AJ Maximum height of attachment	31' 9" (9.68 m)	29' 10" (9.09 m)
AK Bucket sweep angle	131° & 158°	131° & 158°
AL Bucket sweep radius	4' 4" (1.32 m)	4' 4" (1.32 m)
AM Dipperstick sweep radius over teeth — extended	21' 8" (6.60 m)	17' 7" (5.36 m)
AM ₁ Dipperstick sweep radius — retracted	19' 11" (6.07 m)	15' 11" (4.85 m)
AN Boom length from boom foot pin to boom point pin	14' 4" (4.37 m)	14' 4" (4.37 m)
AO Vertical clearance for highest dumping sweep of bucket teeth	1' 11" (584 mm)	3' 6" (1.07 m)
AP Maximum attachment radius with boom at maximum elevation and dipper arm and bucket swing fully in	14' 10" (4.52 m)	12' 6" (3.81 m)
AV Minimum radius of 8' (2.44 m) level bottom at maximum depth	7' 3" (2.21 m)	7' 3" (2.21 m)

NOTE: For units equipped with turntable leveler, add 5.5" (140 mm) to all above ground dimensions and subtract 5.5" (140 mm) from all below ground dimensions



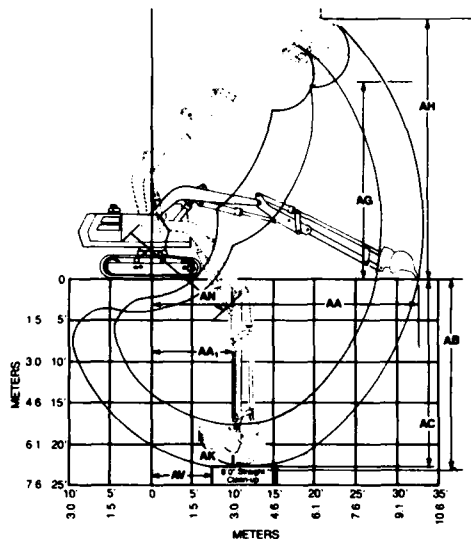
Stick 12,295 lbs (5 577 kg)
 Bucket (131 Rotation) 27,780 lbs (12 600 kg)
 Bucket (158 Rotation) 22,715 lbs (10 303 kg)

Above & Below Groundline Dimensions	Distance from centerline of rotation							
	10' (3.05 m)		15' (4.57 m)		20' (6.10 m)		25' (7.62 m)	
	Side	End	Side	End	Side	End	Side	End
+ 10' (3.05 m)	—	—	—	—	—	—	4,600 lbs (2 087 kg)	4,600 lbs (2 087 kg)
+ 5' (1.52 m)	—	—	—	—	5,800 lbs (2 631 kg)	5,800 lbs (2 631 kg)	5,200 lbs (2 359 kg)	5,200 lbs (2 359 kg)
Groundline 0	—	—	9,100 lbs (4 128 kg)	9,100 lbs (4 128 kg)	7,000 lbs (3 175 kg)	7,000 lbs (3 175 kg)	*5,500 lbs (2 495 kg)	5,900 lbs (2 676 kg)
- 5' (1.52 m)	16,500 lbs (7 484 kg)	16,500 lbs (7 484 kg)	10,800 lbs (4 899 kg)	10,800 lbs (4 899 kg)	*7,700 lbs (3 493 kg)	7,950 lbs (3 600 kg)	*5,300 lbs (2 404 kg)	6,100 lbs (2 767 kg)
- 10' (3.05 m)	17,600 lbs (7 983 kg)	17,600 lbs (7 983 kg)	11,500 lbs (5 216 kg)	11,500 lbs (5 216 kg)	*7,400 lbs (3 357 kg)	8,200 lbs (3 719 kg)	*5,200 lbs (2 359 kg)	5,900 lbs (2 676 kg)

NOTE: Lifting capacities based on unit with "Y" boom and 24 (610 mm) track shoes. Capacities include 1,200 lbs (544 kg) 24 (610 mm) bucket. All specifications comply with SAE J1097. Rated loads do not exceed 87% of hydraulic capacity or 75% of stability.

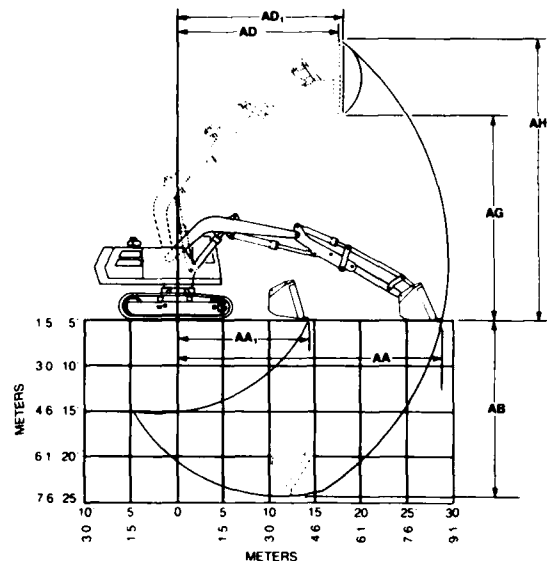
Weight of machine, equipped as shown above, is 40,840 lbs (18 525 kg).

*Indicates Tip



w/DITCH BUCKET **w/BACKHOE BUCKET**

AA	Maximum reach at grade level	32' 1" (9.78 m)	33' 6" (10.21 m)
AA ₁	Minimum reach at grade level	10' 0" (3.05 m)	9' 4" (2.85 m)
AB	Maximum digging depth	22' 6" (6.86 m)	24' 0" (7.32 m)
AC	Maximum depth of cut for 8' (2.44 m) level bottom (straight clean-up)	22' 2" (6.76 m)	23' 8" (7.21 m)
AG	Minimum vertical clearance of bucket from grade at maximum height	24' 5" (7.44 m)	23' 2" (7.06 m)
AH	Cutting edge distance from grade end of highest dump	30' 8" (9.35 m)	31' 2" (9.50 m)
AK	Bucket sweep angle	147°	147°
AN	Boom length from boom hinge pin to tool boom hinge pin	14' 4" (4.37 m)	14' 4" (4.37 m)
AV	Minimum radius of 8' (2.44 m) bottom at maximum depth	7' 6" (2.29 m)	7' 4" (2.24 m)

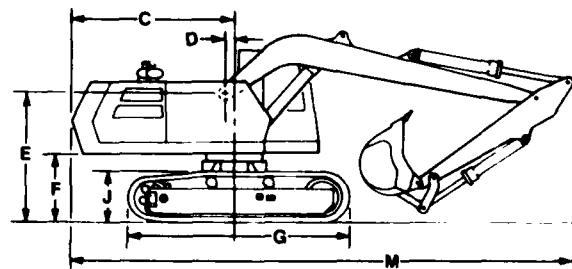
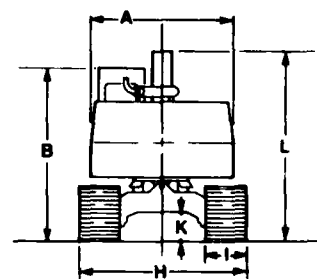


AA	Maximum reach at grade level	28' 9" (8.76 m)
AA ₁	Minimum reach at grade level	14' 4" (4.37 m)
AB	Maximum depth — tip of teeth	19' 2" (5.84 m)
AD	Radius to dipper teeth at maximum attachment elevation	17' 0" (5.18 m)
AD ₁	Radius to dipper teeth @ end of highest dump	18' 1" (5.51 m)
AG	Clearance height @ end of dump	22' 5" (6.83 m)
AH	Maximum cutting height	30' 7" (9.32 m)

DIMENSIONAL DATA

A.	Width of revolving superstructure	7' 11"	(2.41 m)
B.	Maximum height of cab above grade	9' 10 1/2"	(3.00 m)
C.	Swing clearance (radius of rear end from axis of rotation)	10'	(3.05 m)
D.	Distance of boom pivot pin to axis of rotation	1' 1/2"	(322 mm)
E.	Height of boom pivot pin above grade	6' 3"	(1.91 m)
F.	Distance under counterweight to grade	3' 4 1/2"	(1.01 m)
G.	Overall length of crawler	12' 6"	(3.81 m)
H.	Overall width of crawler:		
	Standard 24" (610 mm) shoes	9' 5"	(2.87 m)
	Optional 30" (762 mm) shoes	9' 11"	(3.02 m)
I.	Width of crawler track shoes		
	Standard	24"	(610 mm)
	Optional	30"	(762 mm)
J.	Overall height of crawler tread belt	2' 11"	(889 mm)
K.	Minimum clearance under crawler base to grade	1' 6 1/2"	(470 mm)
L.	Overall height in travel position:		
	"E" Boom w/Lev - 11' 0" (3.35 m)	w/o - 10' 10" (3.30 m)	
	"Y" Boom w/Lev - 12' 2" (3.71 m)	w/o - 11' 10" (3.61 m)	
M.	Overall length in travel position:		
	"E" Boom	30' 0"	(9.14 m)
	"Y" Boom	35' 3"	(10.74 m)

NOTE: For units equipped with leveler add 5 1/2" (140 mm) to all height dimensions.



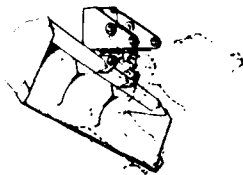
EQUIPMENT ATTACHMENTS

WIDTH	WEIGHT	SAE CAPACITY (STRUCK)
General Purpose Type—Plate Lip		
24" (610 mm)	1,250 lbs (567 kg)	1/2 yd ³ (.37 m ³)
30" (762 mm)	1,400 lbs (635 kg)	5/8 yd ³ (.46 m ³)
36" (914 mm)	1,520 lbs (689 kg)	3/4 yd ³ (.58 m ³)
42" (1.1 m)	1,720 lbs (780 kg)	1 yd ³ (.76 m ³)
Severe Duty—Cast Lip		
24" (610 mm)	1,200 lbs (544 kg)	1/2 yd ³ (.37 m ³)
36" (914 mm)	1,485 lbs (673 kg)	3/4 yd ³ (.58 m ³)
High Capacity		
36" (914 mm)	1,720 lbs (780 kg)	7/8 yd ³ (.67 m ³)
Ditch Forming		
60" (1.5 m)	1,090 lbs (490 kg)	3/4 yd ³ (.58 m ³)
72" (1.8 m)	1,230 lbs (553 kg)	1 yd ³ (.76 m ³)
Front Loader		
60" (1.5 m)	1,550 lbs (703 kg)	1-1/2 yd ³ (1.15 m ³)

NOTE: For heaped capacities, add approximately 20%.

WRIST-O-TWIST®

Wrist-o-twist gives 40° twist action of the bucket to either side of center. Excellent for grading, precision sloping, cleaning ditches, working in close quarters. Exceptional bucket controls.



Crawler tractor-type undercarriage with fully enclosed independently controlled track drives offering counter-rotation and travel speeds to 1.5 mph (2.4 km/h) • 24" (610 mm) triple bar grousers • Sealed brakes • Track rollers and front idlers are permanently lubricated • Total-vision vandal resistant cab with tinted windows • Adjustable bucket seat • Hourmeter • Two windshield wipers • Electric fuel gauge and signal horn • Dry type air filter • Positive oil cooler • Hydraulic oil filtration system • Swing brake • All gear hydraulic track drive • Crawler drive brake • Engine warning instruments • Cold weather start kit • "E" Boom 9' (2.7 m) dipperstick • Case A504 BDT diesel engine • Pilot operated power assisted controls • Remote lube systems for boom, drives and swing gear.

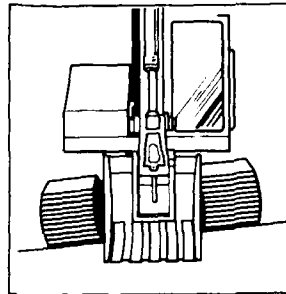
Turntable leveler • Two-speed drive • 30" (762 mm) 3-bar grouser shoes • 10'5" (3.2 m) dipperstick for "E" Boom • "Y" Boom with adjustable tool boom extension • Detroit Diesel 4-71 N diesel engine.

All specifications are stated in accordance with PCSA Definitions or SAE Standards of Recommended Practices, where applicable.

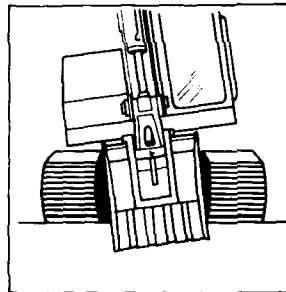
J I Case reserves the right to change these specifications without notice and without incurring any obligation relating to such change.



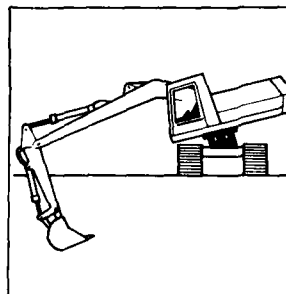
Form No. CE23284



Tilts upper-structure 8½° right or left. Makes slope work easy, more comfortable for the operator. No pre-leveling of terrain is necessary. Easy to dig flat bottom trench on slope.



Taper a ditch, reduce cave-ins, dig at an angle — hydraulically tilt upper-structure to match digging requirements. Increase digging penetration for ripping frost.



When working over the side, tilting upper-structure down lets you dig 2' (610 mm) deeper — or gain 2' (610 mm) in dumping or casting height by tilting upper-structure up. Tilting upper-structure also makes servicing easier.

NOTE:
Turntable leveler is optional.

Sold and serviced by:

Printed in U.S.A.

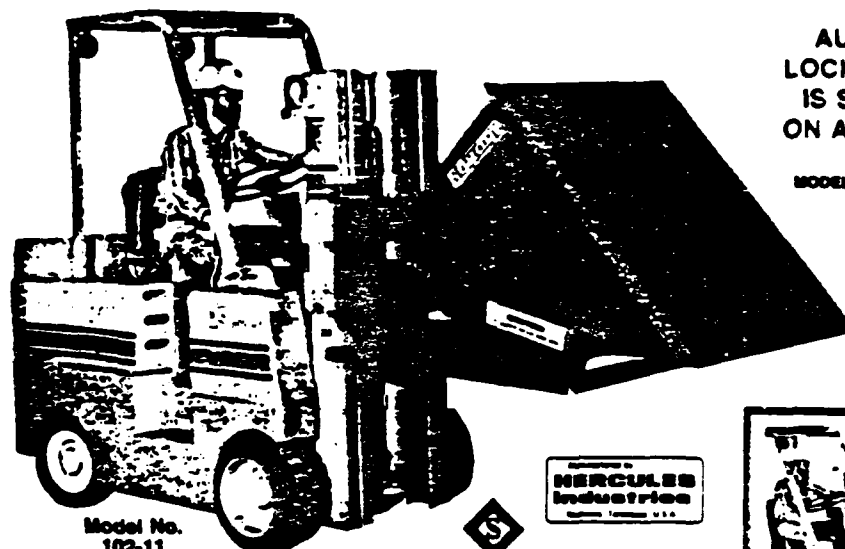
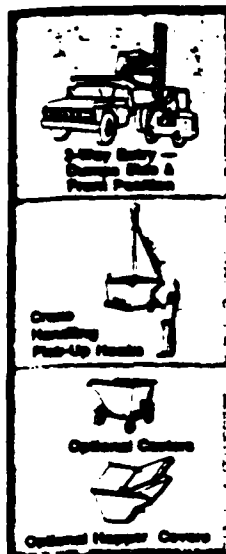
E-4

APPENDIX F

CATALOG DATA FOR THE SELF-DUMPING STEEL HOPPERS

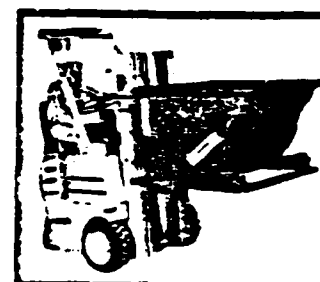
SELF-DUMPING STEEL HOPPERS

THE MOST ECONOMICAL SOLUTION TO YOUR BULK HANDLING PROBLEMS

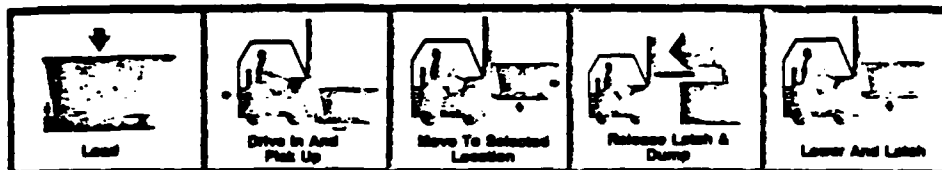


**AUTOMATIC
LOCKING LATCH
IS STANDARD
ON ALL MODELS**

**MODELS 102-10 THROUGH
102-18 ARE
STACKABLE**



FRONT VIEW



FEATURES

HEAVY DUTY MODELS WITH STRUCTURAL STEEL BASES. $\frac{3}{4}$ " (7 GAUGE) FABRICATED AND REINFORCED STEEL BODIES. HEAVY DUTY MODELS DESIGNED FOR FORK LIFT HANDLING OF HEAVY, BULKY-SCRAP, IN-PROCESS MATERIALS AND CASTINGS.

MEDIUM DUTY MODELS ALSO WITH STRUCTURAL STEEL BASES. 12 GAUGE FABRICATED AND REINFORCED STEEL BODIES. THESE MODELS IDEAL FOR HANDLING LIGHT SCRAP, MATERIAL SORTING AND STORAGE, AND EFFICIENT PLANT HOUSEKEEPING. NOT DESIGNED TO BE STACKED WHEN LOADED

OPTIONS

3-WAY ENTRY BASE FOR DUMPING EITHER SIDE (EXCEPT FOR 3, 4 AND 5 CU. YD. MODELS), PLATFORM LEGS; CASTERS (2 SWIVEL — 2 RIGID); 4 PICK UP HOOKS; HOPPER LIDS; OPEN-END MODELS (FOR HANDLING LONG MATERIALS); FINISH PAINT AND STAINLESS STEEL BODIES. CONTACT US FOR QUOTATION IF NOT LISTED BELOW.

Self-dumping hoppers provide efficient material sorting and storage, in-process material handling, scrap collection and dumping, and add to efficient plant housekeeping. Easy one man operation. Dumps automatically when locking-latch is pulled. After dumping, returns to a locked position.

*NOTE: WHEN STACKING HEAVY DUTY MODELS FACTORY RECOMMENDS ONLY 2 HIGH STACKING SHIPPED WITH RED OXIDE PRIMER UNLESS OPTIONAL FINISH PAINT IS SPECIFIED

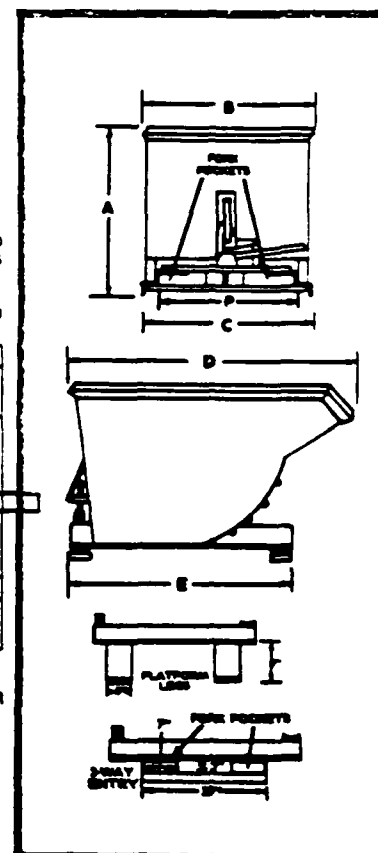
HEAVY DUTY MODELS — 7 GAUGE CONSTRUCTION									
Model No.	Capacity Cu. Yd.	Overall Dimensions (Inches)						Shop Wt. Lbs.	Unit Price
		A	B	C	D	E	P		
102-10	$\frac{1}{4}$	25	32 $\frac{1}{2}$	33	42	40	2 $\frac{1}{4}$ x 24 $\frac{1}{2}$	350	317.00
102-11	$\frac{1}{2}$	30 $\frac{1}{2}$	38 $\frac{1}{2}$	38	46	42 $\frac{1}{2}$	2 $\frac{1}{4}$ x 30 $\frac{1}{2}$	480	337.00
102-12	$\frac{3}{4}$	33	38 $\frac{1}{2}$	39	51 $\frac{1}{2}$	44	2 $\frac{1}{4}$ x 30 $\frac{1}{2}$	512	414.00
102-13	1	37	38 $\frac{1}{2}$	39	62	48	2 $\frac{1}{4}$ x 30 $\frac{1}{2}$	583	425.00
102-14	1 $\frac{1}{4}$	42	43 $\frac{1}{2}$	41	63 $\frac{1}{2}$	51	2 $\frac{1}{4}$ x 42 $\frac{1}{2}$	713	526.00
102-15	2	45	57 $\frac{1}{2}$	57	64 $\frac{1}{2}$	56	2 $\frac{1}{4}$ x 48 $\frac{1}{2}$	825	581.00
102-16	2 $\frac{1}{2}$	50	57	57	67	58 $\frac{1}{2}$	2 $\frac{1}{4}$ x 32	920	647.00
102-17	3	58 $\frac{1}{2}$	63	54 $\frac{1}{2}$	72 $\frac{1}{2}$	59	3 x 32	1250	935.00
102-18	4	58 $\frac{1}{2}$	63	54 $\frac{1}{2}$	72 $\frac{1}{2}$	59	3 x 32	1430	985.00
102-20	5	58 $\frac{1}{2}$	103	54 $\frac{1}{2}$	72 $\frac{1}{2}$	59	3 x 32	1573	1072.00
MEDIUM DUTY MODELS — 12 GAUGE CONSTRUCTION									
103-72	1	37	38 $\frac{1}{2}$	38	62	48	2 $\frac{1}{4}$ x 30 $\frac{1}{2}$	350	339.00
103-73	1 $\frac{1}{4}$	43	51 $\frac{1}{2}$	51	63 $\frac{1}{2}$	51	2 $\frac{1}{4}$ x 42 $\frac{1}{2}$	503	380.00
103-74	2	46	57 $\frac{1}{2}$	57	64 $\frac{1}{2}$	56	2 $\frac{1}{4}$ x 48 $\frac{1}{2}$	583	405.00

FOR TENNESSEE

TO ORDER 3-WAY ENTRY BASE; HOPPER LIDS; LONGER PLATFORM LEGS, OPEN END MODELS FOR HANDLING LONG MATERIALS OR STAINLESS STEEL BODIES, CONTACT US FOR QUOTE.

TO ORDER OPTIONS, ADD SUFFIX TO MODEL NUMBERS AND PRICE SHOWN BELOW

Model No. Suffix	Description	Price
A	Casters, (8" Dia.) Rubber	104.00
B	Casters, (8" Dia.) Phenolic	84.00
C	Platform Legs, Up to 6"	84.00
F	Pick Up Hooks (4)	38.00
G	Finish Paint (Specify Color)	41.00

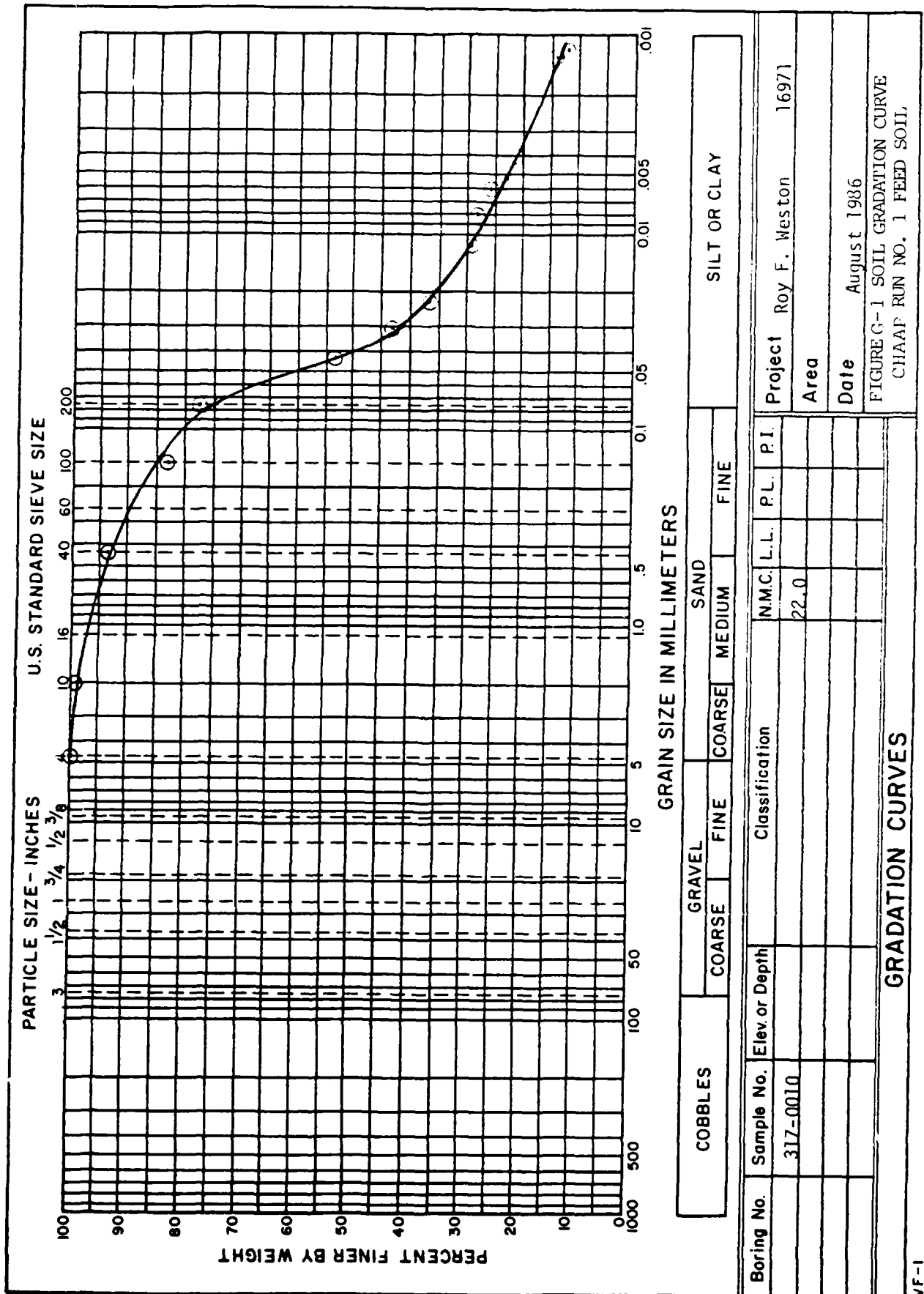


PRICES ARE FOR YOUR ESTIMATING CONVENIENCE. PLEASE CALL OR WRITE FOR CURRENT QUOTATIONS



APPENDIX G
SOIL GRADATION CURVES FOR CHAAP TEST RUNS

0492B



COBBLES		GRAVEL		SAND			SILT OR CLAY	
	COARSE	FINE	COARSE	MEDIUM	FINE			
Boring No.	Sample No.	Elev. or Depth	Classification		N.M.C.	L.L.	P.L.	P.I.
	317-0010				22.0			
Project					Roy F. Weston 16971			
Area								
Date					August 1986			
FIGURE G-1 SOIL GRADATION CURVE								
CHAAF RUN NO. 1 FEED SOIL								

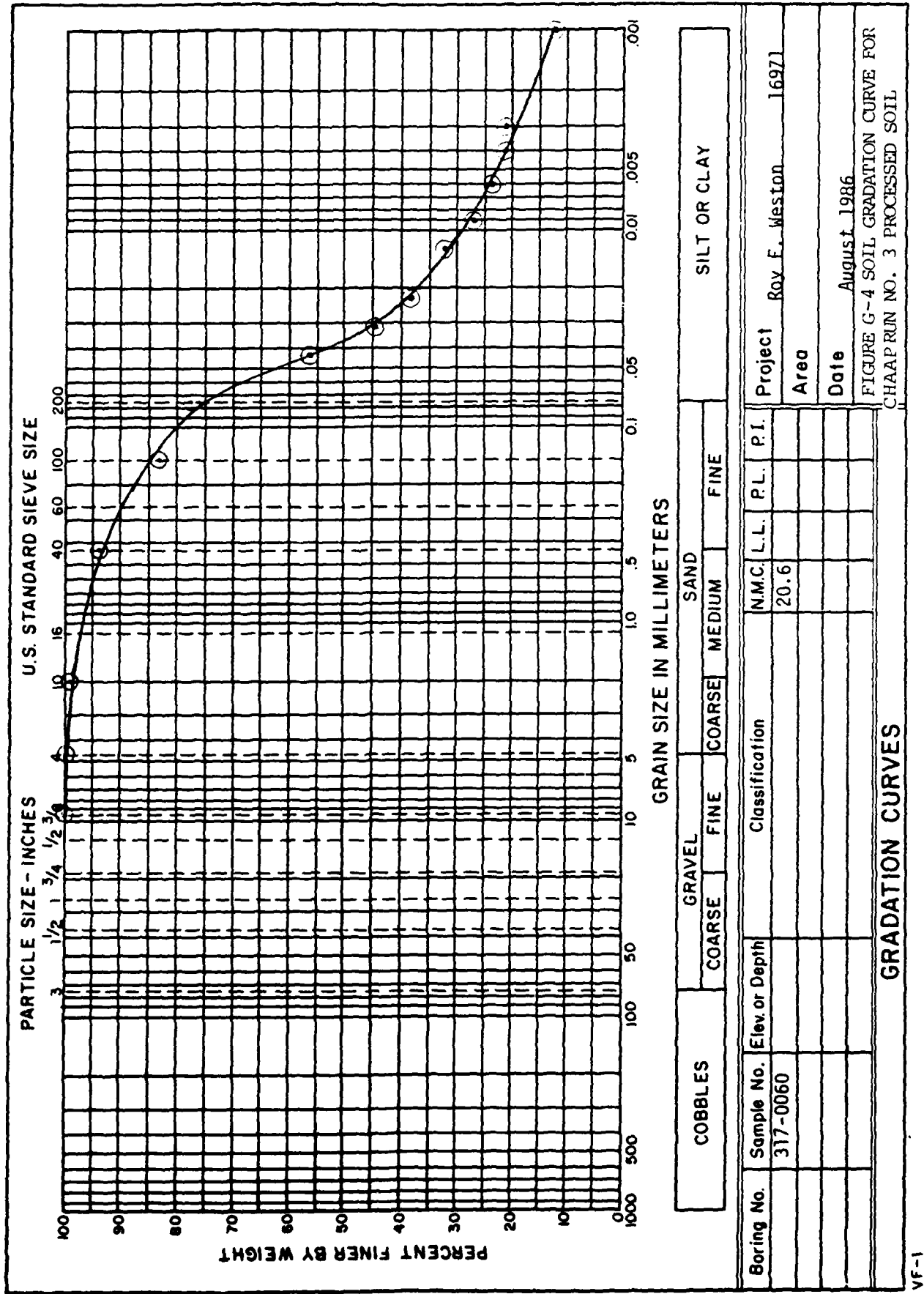




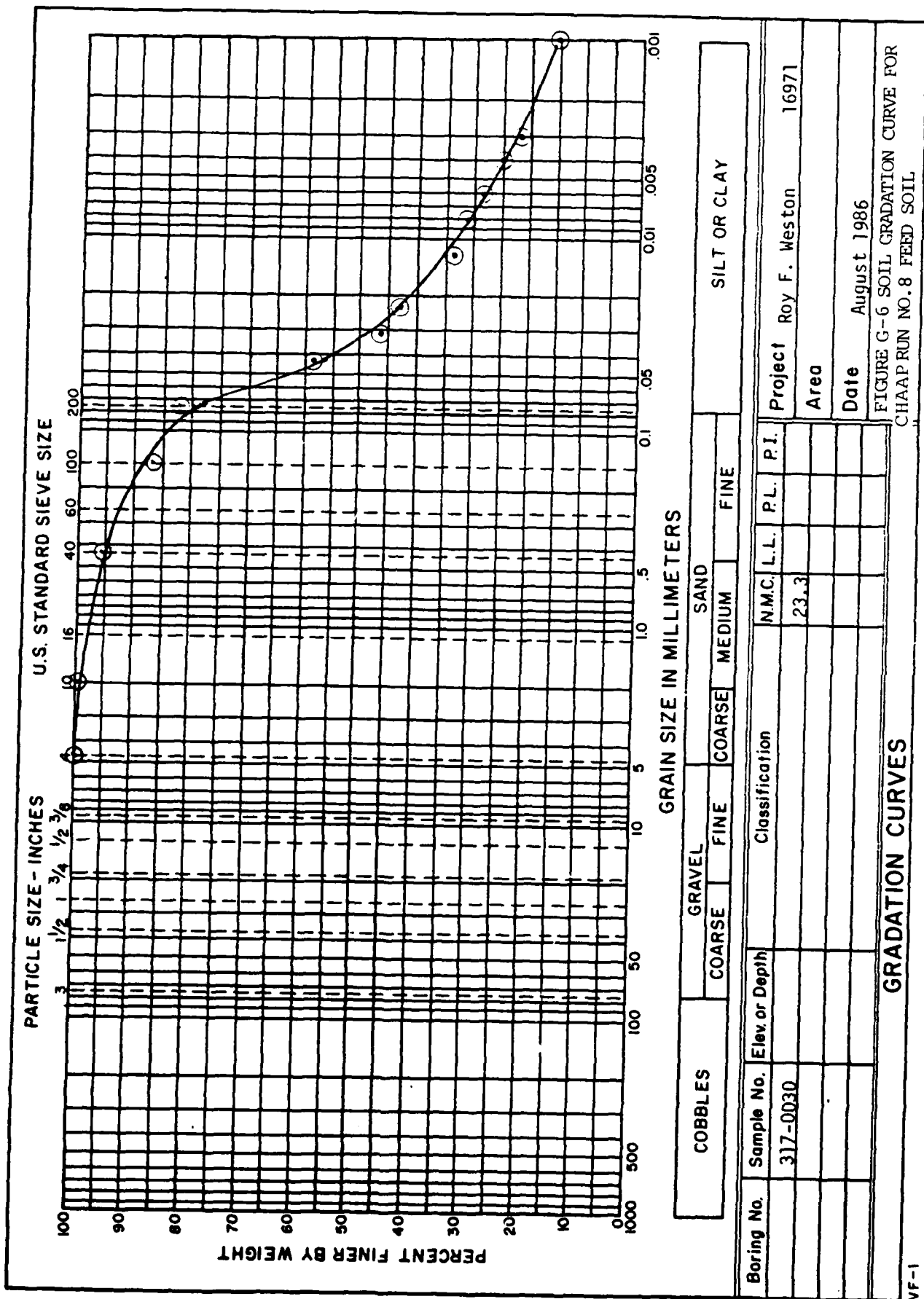
FIGURE 24

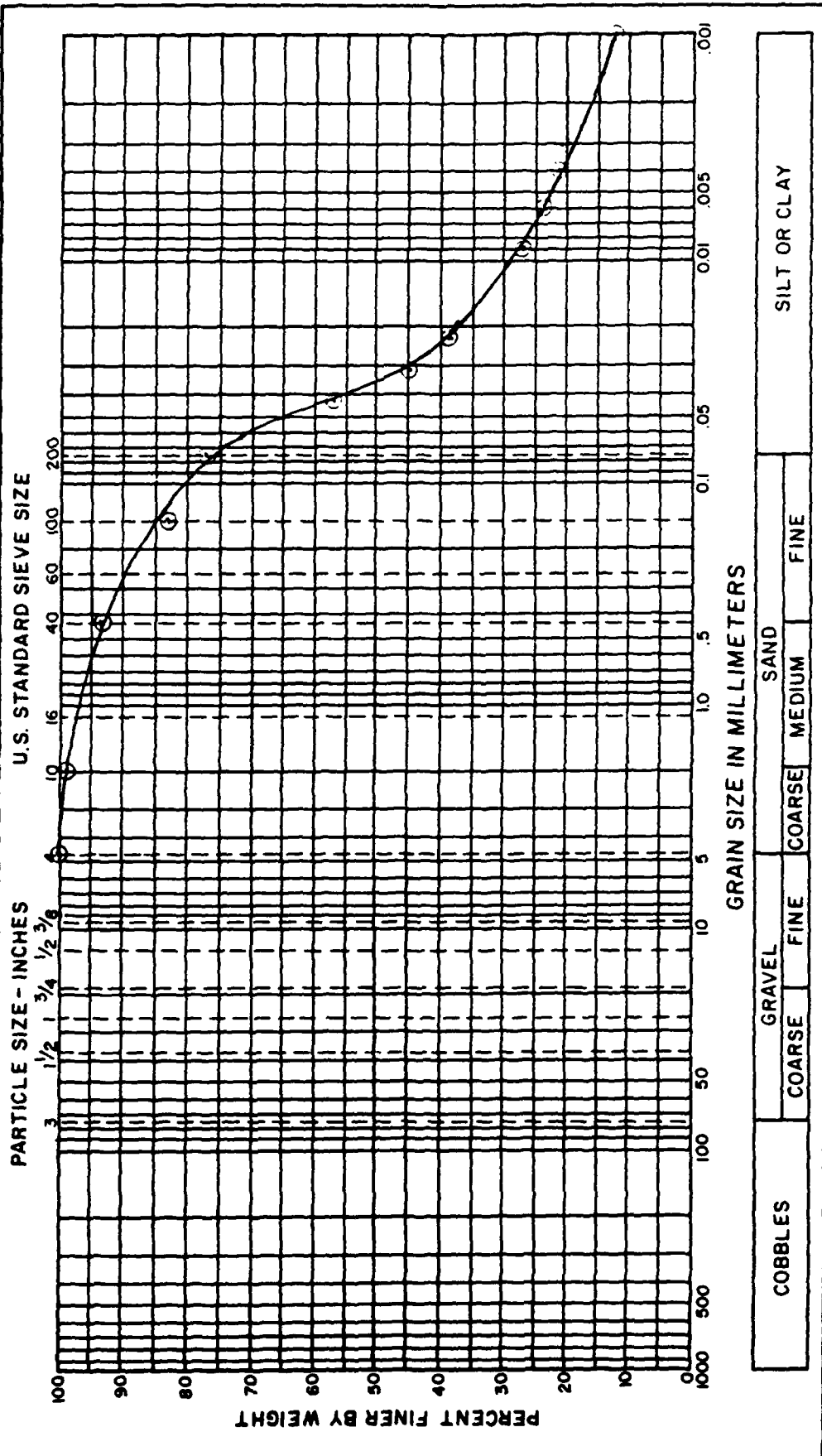
SOIL GRADATION CURVE FOR

CAAP RUN NO. 4 PROCESSED SOIL

WILL BE PROVIDED IN

FINAL EDITION





Boring No.	Sample No.	Elev. or Depth	Classification	N.M.C.	L.L.	P.L.	P.I.
	317-0040			21.7			

GRADATION CURVES

Project Roy F. Weston 16971

Area

Date August 1986

FIGURE G-7 SOIL GRADATION CURVE FOR CHAAP RUN NO. 8 PROCESSED SOIL

FILMED
5-8